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OCTOBER 1925

PRODUCTION MEETING NUMBER

SOCIETY OF AUTOMOTIVE ENGINEERS INC
29 WEST 39TH STREET NEW YORK

September 15, 1925

I ARRIVED back in Philadelphia last night from a two weeks' trip through some of our Southern states in my Chrysler Six Coupe—Maryland, Virginia, West Virginia and North Carolina. From all directions cars and cars and more cars were battling their way towards Miami, Sarasota and St. Petersburg. The passengers were floundering all over the cars, and the cars were floundering all over the roads. I talked to a lot of these people and they will not tell you that motoring is fun. They will all tell you it is torture.

You Members of the Society of Automotive Engineers should insist that the President and each member of the Board of Directors of your Company take a similar two weeks' tour in any car with uncontrolled springs.

And the Advertising Manager—the man who talks about this velvety gliding stuff—should also be made to go along. I'll bet a good Fall hat they will come back and let you Engineers engineer your cars the way you want to.

THE
JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE ENGINEERS

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H. L. HORNING, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. XVII October, 1925 No. 4

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

'Frisco Comes Through

FOR many months Society members in San Francisco have composed an active group of the Society and have looked forward to the time when the formation of a Section could be arranged. By the inauguration on Sept. 28, of a Section including members in the San Francisco territory, the wishes of many enthusiastic Society members have been fulfilled. The members were very much gratified to have President Horning come to San Francisco to officiate at the inauguration.

The Society as a whole extends best wishes and assures the new Section of its utmost confidence.

Transportation Meeting, Nov. 13 and 14

THE date of the Transportation Meeting has been changed to Nov. 13 and 14 to provide for more satisfactory meeting accommodations than would be available on the dates originally set. The topics to be discussed at the technical sessions include standardization, freight handling, store-door delivery, and motorbus operation. A Transportation dinner, a street parade of transportation equipment and a plant inspection are included in the program.

Additional details concerning this important national event will be found on p. 315 of this issue of THE JOURNAL.

"Coach" or "Brougham"

THE resurvey of body names now being used by the different car builders printed on p. 319 of this issue indicates the need for further simplification. As matters now stand it is impossible to determine, when the term "brougham" is used, whether a car similar to a limousine, but without the permanent top over the driver's seat, is referred to or a four-door close-coupled sedan or a five-passenger coupe.

Current practice seems to indicate that "coach" is a two-door five-passenger closed body, whereas "brougham" is a four-door five-passenger closed body. Several companies, however, call a two-door job a "brougham," and others call a four-door job a "coach."

The survey, which will be used by the Passenger-Car Body Division to determine if changes in the S. A. E. Standard nomenclature are warranted, should be of help to car builders in deciding what body names should or should not be used for the body types to be included in their 1926 production.

Frenchmen Coming to Aeronautic Meeting

A DISTINGUISHED group of engineers will participate in the aeronautic meeting to be held at the Hotel Astor, New York City, on the afternoon and evening of Oct. 7. Word has been received by cable that P. E. Flandin, president of the Aero Club of France, and Louis Breguet, prominent French airplane manufacturer, will honor the Society by their presence.

An afternoon session devoted to the consideration of design and construction, an aeronautic banquet and an evening session devoted to operation are included in the program that is presented in detail on p. 315 of this issue of THE JOURNAL. A perusal of these details should convince a large number of our members that the meeting will be one of the most valuable ever arranged by the Society.

Service Engineering Meeting, Nov. 9 and 10

CHICAGO has been chosen as the scene for the Service Engineering Meeting and Nov. 9 and 10 as the days when the technical sessions will be held. The Society will be responsible for two technical sessions and the National Automobile Chamber of Commerce, with which the Society is cooperating, will arrange two others.

Lubrication and corrosion of internal-combustion engines will be the topics discussed at the first S. A. E. Session, whereas the diagnosing and remedying of car troubles will supply subject matter for the second.

Further information will be found on p. 316 of this issue of THE JOURNAL, and detailed announcements will be brought to the attention of the members in a *Meetings Bulletin* and in the November issue of THE JOURNAL.

National Directory of Commodity Specifications

THE National Directory of Commodity Specifications that is being published by the Department of Commerce is described more fully on p. 321 of this issue of THE JOURNAL. The compiling of these data which are references to existing commonly used specifications and

the industrial organizations and Governmental Departments issuing them, has consumed a considerable amount of time and effort by the Department of Commerce, as well as by a large number of industrial organizations represented on the Advisory Committee that was appointed to cooperate with the Department. The Directory should be of much value to the industries in general throughout the Country as well as abroad toward reducing the present variety of slightly different specifications that are used for given commodities, and helping to reduce some of the wastage in industry that is known to be preventable.

Production Meeting A Success

A NEWS account of the National Production Meeting of the Society, that was recently held in Cleveland, is presented on the opposite page. Several of the papers are printed in this issue and others will follow in subsequent numbers.

From the standpoint of technical papers and discussion the event this year was a huge success: it was, in truth, a "Production Meeting for Production Men." Considering the total registration, approximately 335, which represents some 60 per cent of the production men in the Society, the sessions were well attended and it was remarked that those in attendance were, for the most part, production men who had come to profit by the discussions.

In view of the attractiveness of the program that the Production Meeting Committee provided this year, it is surprising that a larger group of production men did not attend the meeting that was open to all, non-members included. Many of those who did attend remarked that the absentees had missed an opportunity of great value both from a technical and a social standpoint.

One of the pleasant features of the meeting was the cooperation of the American Society for Steel Treating.

Membership Increase

THE Membership Committee is very much gratified by the splendid response of the members to its request for cooperation in increasing the membership of the Society. In the 12 months, up to Aug. 31, 902 applications for membership were received. The rate at which applications have been received this year has increased 30 per cent as compared with last year.

Every effort will be made to encourage the presentation of more production papers at National and Sections meetings. Economy in manufacture is becoming more and more important. The Society has always been more or less active in this phase of engineering, but, because of the demand on the part of manufacturers, greater attention must be paid to this work. The members are urged to make this known to all production managers and department superintendents who are not members of the Society. Show them this Production Number of THE JOURNAL. Ask them to file their application for membership and to take an active part in the work of the Society. This will mean much to them in this forward movement for economical production, and their cooperation will mean much to the Society.

It is suggested also that all available younger men, under 30 years of age, who are engaged in engineering work, be urged to join the Society. Membership will serve to broaden their sphere of engineering knowledge, promote more rapid advancement for them, and make them more valuable to their employers.

Section officers who have to do with the making of programs for meetings are urged to bear in mind that the members are interested in design, production, fleet operation, and maintenance and service, in connection with automobiles, motorcoaches, light commercial vehicles, heavy-duty trucks, tractors, aircraft, motorboats, motorcycles, stationary internal-combustion engines and other transportation mediums closely associated with the internal-combustion engine. Members of Sections Membership Committees should also bear this in mind. They are requested to send to the Society's headquarters the names of fleet superintendents connected with motorcoach lines, electric railways, department stores, and truck transportation companies, and of the service managers connected with the larger service and dealer organizations throughout the Country, as well as the names of engineers and production department superintendents.

Non-Glaring Head-Lamps Necessary

SINCE electric lights mounted in paraboloidal reflectors have been used in motor-vehicle head-lamps, the glare emanating from this form of light-source has been a cause for complaint. A considerable demand exists on the part of motorists for head-lamps with which obstacles can be discerned at a considerable distance and to make lamps to meet this requirement is a very simple matter. However, because of well-known physical laws, long-distance illumination necessitates a light-source of a candlepower that is decidedly glaring to human eyes. To reconcile the conflicting requirements of a desire for long-distance illumination and the elimination of glare, compliance of the light-distribution with the well-known Illuminating Engineering Society and this Society's specifications is now demanded by about 15 States of the Union and by Ontario and Quebec. Some of the States, California and Oregon, require a light distribution slightly different from that specified by the two societies.

Nearly all States that have adopted the above-named specifications encounter difficulty in enforcing their laws. According to A. W. Devine, engineer in charge of equipment section, Massachusetts Registry of Motor Vehicles, and chairman of the Eastern Conference of Motor Vehicle Administrators, from 75,000 to 100,000 complaints have been made in Massachusetts alone in a short time. Therefore, very far-reaching and numerous demands pertaining to the design, construction and mounting of the head-lamps are being discussed by some State officials. This condition of affairs may lead to extreme difficulty for manufacturers inasmuch as it is likely that conflicting, as well as drastic, legislative demands will be made in various States.

Obviously, with the growing need for night-driving, highly satisfactory and also uniform head-lamp regulations are requisite. Anything else will militate against normal development in the use of automobiles.

The Society is making every effort to assist in improving the present condition. A committee, of which T. J. Lítle, Jr., is chairman, will scrutinize the equipment currently used, particularly from the standpoint of its adequacy for affording legal and satisfactory illumination. This committee will cooperate intimately with manufacturers. Head-lamp illumination as a whole must be improved if the fear of night-driving is to be thoroughly rooted out. The establishment of a new code of ethics on the subject may be necessary. The responsibility for bad lights does not in a majority of cases rest with the driver. It is hoped that the committee will receive the unanimous support of manufacturers in its work.

PRODUCTION MEN MEET

Excellent Papers and Discussions Presented—Entertainment Features Enjoyed

Judging from many comments that were made at the National Production Meeting held at the Hotel Winton, Cleveland, Sept. 14 to 16, the quality of the technical papers and discussions presented at the sessions was fully up to the standard established by previous meetings. There were six technical sessions devoted respectively to the topics, Sheet-Steel Fabrication, Training, Gear Production, Machine Tools (two sessions), and Inspection. A Production Dinner was held on the evening of Sept. 15 and was well attended by members of the Society and guests. A complete news account of the meeting will be found in the following paragraphs. Several of the papers are printed in full in this issue of THE JOURNAL and others will appear in later issues.

THE ATTENDANCE

The total registration for the technical sessions reached 335, 11 less than the number that attended the Production Meeting in Detroit last year. This total does not include those among the 200 that attended the Production Dinner who failed to register.

A survey of the registration indicates that 87 per cent of those listed were directly connected with the manufacture of automotive equipment. The remaining 13 per cent includes sales representatives, representatives of the trade press, students, employes of the Society and Government representatives.

In view of the attractiveness of the program provided this year by the Production Meeting Committee, it is surprising that a larger proportion of the members did not attend the Production Meeting. The various attractions, aside from the Production Meeting, that were in progress simultaneously would have been expected to augment the attendance rather than detract.

From the "quality" standpoint this year's Production Meeting was very satisfactory; men of the right type were reached and their participation in the discussion of various papers clearly indicated their interest. Real significance attaches to the fact that nearly 90 per cent of all those who attended the sessions were directly connected with the industrial branches that actually produce.

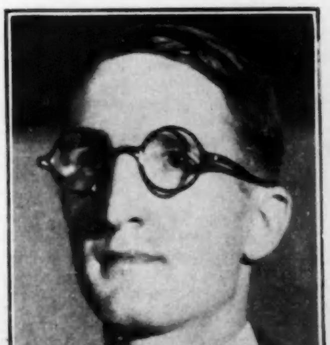
HOT STAMPING PROCESS EXPLAINED

Method Said to Be Adapted to Rapid Attainment of Small Production at Low Cost

According to G. F. Keyes, of the Mullins Body Corporation, who presented a paper on Hot Stamping, at the Sheet Steel


H. W. Alden
Gear


John Jaschka
Sheet Steel


A. H. Frauenthal
Inspection


John Younger
Training

CHAIRMEN AT FOUR OF THE SESSIONS

Session, this process is considerably more complicated than that employed in making cold drawn stampings and it is not well fitted to large production. In cases where small production is desired, however, or whenever it is necessary to begin production with little delay, the hot stamping process is advantageous, owing to the possibility of making the most difficult stampings in a comparatively short length of time at a reduction in tool costs. Mr. Keyes included in his paper a detailed exposition of the methods used and a description of the equipment employed.

Making Models, Castings and Dies

He stated that either wax, wood or plaster-of-paris models can be used, the type of model being determined by existing conditions. As an example, he cited the case where a designer prefers to make an outline drawing of a fender or body panel and work out details in the model. Wax would in this case be the best material to use inasmuch as it lends itself to changes that can be made with very little effort. Plaster-of-paris models are used when a reproduction of a hand built body is desired.

A plaster cast can be taken from the sample panels, a recast made therefrom and the recast set up in the form of a model. When complete body drafts are available and a design is predetermined, models made of wood in the conventional manner are preferred. Upon completion of the models the plaster casts are made; they are built into patterns representing finished dies. From these patterns the semi-steel dies are cast. This requires a special set-up in the foundry to insure that the dies come from the sand true to pattern. Sufficient shrinkage takes place to allow for finishing the die surfaces.

In some cases, the spotting casts are made from the die patterns, depending upon the method of machining the dies; otherwise, the die pattern is set up on the Keller machine which reproduces the die pattern, leaving the die ready for final finishing. The dies are then planed and drilled to fit either the drop hammer or the single-action press. The choice between these two machines depends upon the type of stamping to be made.

Before the dies are set in the press, they are filled with "pick-ups," a single pick-up representing one drawing operation; the number usually runs from three to seven, depending on the depth of the draw. After all the pick-ups have been made, the die is set in the press to have the portion of the die cast; an improvised mold is made around the top of the die and lined with clay; then this mold is filled with molten lead that forms the top die.

As soon as the latter is cold, it is attached to the ram of the press and is raised clear of the die, a heavy gage plate is placed on top of the pick-ups and the top die is dropped in case the drop hammer is used or squeezed if a single-action press is employed. This operation forms the heavy plate into the shape of the first operation.

This plate is attached to the upper die and stampings are then run through the press and partially formed. This is done with the metal cold and is called breaking down. The operation is repeated until all pick-ups have been removed from the lower die and attached to the upper; then a new upper die is made to conform to the sand shape of the semi-steel die. The upper die is then covered with a heavy gage stamping, with an asbestos lining between the stamping and the lower die to protect the lead from the heat.

After the new die has been made and lined or covered with steel or asbestos, the hot run is made and stampings are heated to a cherry red and run through the dies. This operation requires considerable skill as shrinkage and imperfections are removed during the operation.

After the stampings have been run hot and have cooled, they are re-run through the die with irons added to the die to sharpen the corners, to set beads and to remove any shrinkage caused by the cooling of the stamping.

In concluding his remarks Mr. Keyes asserted that important savings are made possible by the use of the hot stamping process. It has been found desirable, he said, to combine the use of hot and cold stampings in the same job, making the more difficult stampings by the hot process.

G. F. Keyes

M. R. Wells

Discussion Brings Out New Facts

In commenting upon Mr. Keyes' paper, L. L. Williams, of the Cleveland Automobile Co., requested information concerning the adaptability of hot stamping to the manufacture of parts requiring accuracy as to size. Mr. Keyes stated that the hot stamping process is not to be recommended in cases that indicate the need for extreme accuracy. It could be applied, however, to the stamping of the half portion of an axle, for example, in the case where there is no straight draw.

Answering a question from W. G. Careins, of the Ajax Motors Co., regarding the dividing line between hot and cold stampings from an economic standpoint, Mr. Keyes said that this depends largely upon the degree of complication of the stamping. As an illustration he mentioned one job, with a production of 1500 pieces, where the hot stamping process was proper to be used. He stated, however, that in case the production should increase by 1000, it would be economically sound to utilize cold drawn tools.

The speaker further stated that asbestos is used to build up the contour of the molds and also as an insulator. The stamping itself was said to conform to the shape of the die. After cooling, certain strains remain in the stamping and cause it to lift from the die, but this trouble is remedied in the final operation.

In cases where beads prevail, the latter become injured on the female portion of the die after approximately 1500 or 2000 stampings are produced. Re-dressing is then required.

The answer to a question from Harry Rodemeyer, of Barnes, Gibson & Raymond, Inc., was that the comparative life of dies for the hot stamping process and the cold stamping process depends largely upon the presence or absence of sharp corners on the die. He said that a production of 20,000 stampings from one die without sharp edges was practical, stating, however, that the life of dies for cold stamping is longer, and that the use of the cold process is therefore advantageous for large production.

Mr. Palmer, of the American Rolling Mill Co., inquired about the comparative expense of finishing after stamping. Mr. Keyes stated that owing to the necessity of removing scale caused by the heat it is more expensive to finish the hot stamping than the cold. Pits, caused by scale between the die and the stamping, are easily removed along with the scale by sand blast methods.

M. R. Wells, of the Cleveland Automobile Co., suggested the possibility of eliminating scale formation by heating the parts in a salt bath.

Answering a question asked by R. P. F. Liddell, of Motor Improvements, Inc., Mr. Keyes said that the hot stamping die is made of semi-steel, that is, a composition of cast iron to which steel has been added in the cupola and not in the ladle. This composition contains from 10 to 20 per cent of steel. The beads on hot stamping dies are inserts milled from mild steel. In heating, it is the practice to keep the

temperature below the scaling temperature of steel, that is, from 900 to 1200 deg. fahr.

In reply to an inquiry from J. S. Schneider, of the Bossert Corporation, the speaker stated that hot stampings would be found stiffer than cold stampings because in the former the strains have been removed.

In reply to a question from W. A. Irwin, of the American Sheet & Tin Plate Co., Mr. Keyes said that the best grade of auto body steel suitable for deep drawing should be used. The sheet should not have experienced excessive amounts of cold rolling; this on account of scaling.

Referring to a question of W. C. Templin, of the American Sheet & Tin Plate Co., the speaker stated that more stretcher-strains prevail when the cold process is used.

SHEET STEEL FABRICATION

Economical Methods and Equipment for Utilizing Sheet Stock Explained

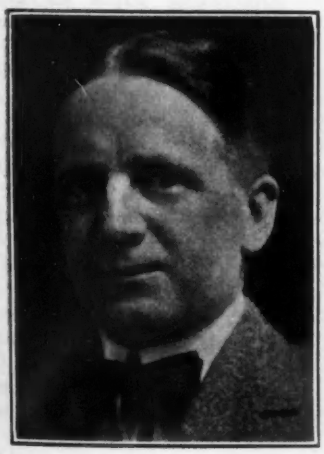
Inasmuch as from 25 to 30 per cent of the weight of an average passenger-car is made up of the sheet steel or strip steel used in its construction and in view of the fact that approximately 60 per cent of the cost of a piece is in the stock, the opportunity to reduce the costs by conserving the stock becomes apparent. Practices designed to effect economy in sheet steel fabrication were explained and the equipment for the accomplishment of savings was described vividly in a paper by Syd Smith, of the Studebaker Corporation of America, that was admirably presented in the absence of Mr. Smith by R. I. Mowry, of that organization.

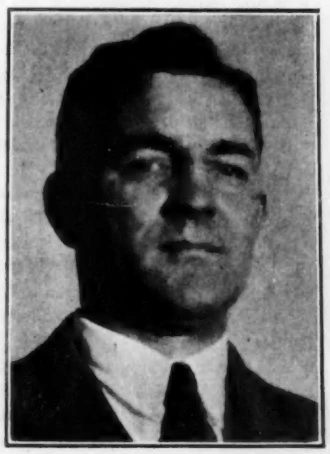
Economy the Watchword

With economy as the watchword, the Studebaker Corporation has devoted particular attention to the utilization of scrap from large pieces in the manufacture of small parts. A card-index file quickly provides information as to the possibility of making new pieces from scrap material, and small pieces of scrap are welded together into such regular shaped and sized sheets of stock as would be suitable for parts like dust-pans, seat-pans and running-boards.

So great has been the progress within the last few years in the production of parts from sheet steel that they have largely superseded castings and forgings, particularly those used as body parts. Great possibilities still exist in this direction, however, even to the extent of making phaeton tops from a single sheet of welded steel. With tops thus made, it was stated, sounds produced by vibration can be largely eliminated and stiffness and similar qualities can be provided by proper shaping and reinforcing.

Although sheet metal parts do not compare favorably with iron castings when considered on a basis of the cost per pound, they are said to make an excellent showing on the basis of strength costs. To cite concrete examples and to illustrate typical methods of producing sheet metal parts, Mr. Smith's paper, printed in full elsewhere in this issue of The Journal, follows the progress of several automobile parts, including the shroud, tonneau and side-rails, during their fabrication. The manner of assembling various parts is also included.


Syd Smith


R. I. Mowry

An Interesting Discussion

Answering J. W. Mitchell, of the Paige Detroit Motor Car Co., the speaker stated that the sheet stock is purchased as near to size as obtainable, the object being to leave the least possible amount of scrap. The stretcher-strain left in the stamping after roller leveling is removed by running the stampings through the press immediately after the leveling operation.

It developed in the discussion of a question by R. Z. Hopkins, of the Hudson Motor Car Co., that after the flash welding process is completed, the parts are finished before they are placed on the body; the only finish on the line being that required because of imperfections that developed along the line. Mr. Mowry stated that the welds are tested in the laboratory on the twisting machine.

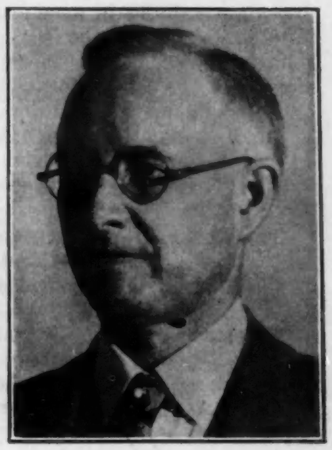
John H. Jaschka, of the National Malleable & Steel Castings Co., acted as chairman of the Sheet Steel Session.

GREAT INTEREST IN TRAINING SESSION

Agreement on Main Issue and Disagreement on Other Cause Lively Discussion

The benefit, from the production viewpoint, to be derived from the training of foremen and other employes was the theme of the Training Session of the annual Production Meeting. This session, which convened in the Ballroom of the Hotel Winton, Cleveland, on the afternoon of Sept. 14, was well attended, and the three papers that composed the program for the session were enthusiastically received by those present. Agreement as to the importance of training was tempered by a certain amount of disagreement relative to some features of the training, with the result that a lively and interesting discussion was provoked.


Lillian M. Gilbreth


F. T. Jones

Training for Production

Lillian M. Gilbreth, of Gilbreth, Inc., after a cordial introduction by John Younger of the Ohio State University, chairman of the Training Session, presented a paper entitled Training Employes in Production Work; this paper is printed in full in this issue of The Journal. Stressing the importance of production by saying that whatever is done in industry is measured by its effect upon production, Mrs. Gilbreth stated her view that all training done in industry is really training for production, whether the worker being trained holds a job in the production department itself or in the selling department, the accounting department or elsewhere. In the one case, he is trained directly for production; in the other cases, he is trained for production, though

indirectly. She also called attention to the fact that training for production is given, even when no actual training department exists, and she cautioned against the fallacy of thinking that, in the absence of a training department, training is not costing a plant anything.

The importance of an adequate recording system was emphasized, because without dependable records the success or failure of an enterprise cannot be evaluated.

The speaker said that the aims of training for production were to make: (*a*) a better worker in the particular job, (*b*) a better member of the industry and (*c*) a better member of society. She stated that the first aim is the one to be most directly considered, as it results, if successful, in enabling the worker to make good in his particular job with a consequent benefit to himself and to his employer.

Mrs. Gilbreth dwelt on the factors of teaching that enter into any system of training, namely, what is to be taught, who is to teach it, when is it to be taught, where is it to be taught, how is it to be taught, and why is it to be taught.

A valuable and interesting accompaniment to the paper was the showing of slides illustrating many of the points brought out by the speaker.

"Conferences" versus "Training"

Foreman-training has passed the point in its career when arguments are to be urged for or against its desirability. It is no longer necessary to ask whether training should be given, but discussion may still be profitable in regard to what training shall be given and how. These remarks formed the introduction to an interesting paper on Products and By-products of Foremen's Conferences, prepared and presented at the Training Session by Franklin T. Jones of the White Motor Co. It is planned to publish, in an early issue of The Journal, this paper, which discusses the technique of introducing, conducting and auditing a system of foreman-training in a manufacturing organization.

Commenting on the fact that if he were himself a foreman he would resent "being trained," the speaker advocated the use of the term, "foremen's conferences," to designate this type of education.

Mr. Jones entered upon the main theme of his paper by referring to four publications from which information can be obtained, relative to subjects for foremen's conferences. They are as follows:

The Foreman—Department of Labor Training Bulletin No. 26—U. S. Training Service, 1919.

The Industrial Supervisor—Westinghouse Electric & Mfg. Co., 1923.

Foreman Training—Pittsburgh Personnel Association, June 1, 1924.

Foreman-Training Methods—American Management Association (formerly National Personnel Association), 1922.

The first reference, The Foreman, is out of print, but the speaker expressed a hope that it be reprinted and given an even wider distribution. The chapter headings in this publication, said Mr. Jones, give a good idea of the subjects requiring discussion in any series of foremen's conferences. The second publication describes the development of supervisory training on the part of the company that issued it. The third article, he stated, is sufficiently specific to serve as a guide for any company that is considering the introduction of any form of foreman training. The fourth reference contains the following divisions, which are self-explanatory: the leader method, the conference method, the text study method, field training of foremen, following up of foreman-training work, and production conference versus foreman training.

Obtaining conference leaders was the next topic discussed by Mr. Jones. Comment was made upon the fact that the large majority of foremen have come up from the ranks and consequently have, to a great extent, the viewpoint of the worker. The foreman, said Mr. Jones, is naturally suspicious when he is called into a production conference and told about a new policy or given directions for changes within his department, as he is inclined to wonder what is being put over. If his name is listed as one of those to take foreman-training, he will accept the appointment just as he would accept any other order given to him by a superior, but he may not be at all convinced that the training will be useful to him or that it will really promote the interests of the company. For this reason, according to Mr. Jones, it is better for the leader of a group receiving training to be a person who has no authority over the individual members of the group. In this connection the speaker said:

> It is therefore a mistake for the initial foreman-training to be carried on by a conference leader who is a member in authority of the organization. Only in the rarest instances will he be able to gain frank and fair discussion and a full expression of those ideas which it is most important that the members of the group consider. It will always be felt that such a person will make use of the information brought out possibly in a hostile manner.

Continuing, Mr. Jones said:

> The outsider, however, must be a man of judgment who can lead the discussion wisely in directions profitable to the company. It is advisable that he spend a considerable period of time inside the factory itself, looking over departments, observing methods of manufacture, talking with executives, and making himself virtually a member of the organization. In other words, he must master the policies and principles of the organization as well as the product if he expects to attain more than mediocre success with the group of foremen for whom he is conducting conferences.

Emphasis was laid by the speaker on the necessity for proceeding with the conferences in such a way that the method used should inspire confidence.

It was recommended that small successive groups of foremen participate in conferences, rather than large or simultaneous groups. Mr. Jones believed that in this manner interest would be better aroused and more successfully maintained, and the level of thought and practice inside the organization would be permanently advanced. The advisability of taking steps to make the results permanent by carefully planned follow-up was stressed, and a list of subjects was suggested that might be used in continued study.

An interesting feature of the paper was a summary of the products and by-products that resulted from a series of foremen's conferences, this summary being obtained in answer to a letter sent out to foremen, superintendents and higher executives in a manufacturing organization at the conclusion of a series of conferences. The products and the by-products were tabulated, and the speaker expressed the opinion that the by-products from such conferences are often of greater value than the direct products. As a specific illustration of products and by-products of foremen's conferences, it was shown how ratings and rankings were developed in one organization.

Receptive Attitude Essential

Louis Ruthenburg, of the Yellow Sleeve Valve Engine Works, Inc., presented a most interesting paper on The Training of Shop Foremen. In his introductory remarks, he made the statement that he did not claim to be telling anything new but that his purpose was to give an outline of one method of thinking about a big subject.

Mr. Ruthenburg brought out the need for efficient foreman training by pointing out that the foreman is an important factor in the matter of low costs and high quality. He analyzed the essential nature of the foreman's job, characterizing him not simply as the master mechanic over a group of workers but as the business manager of his department who must be trained so that he can get good results without the club of direct authority.

In planning a foreman-training program, said Mr. Ruthenburg, method is initially of much greater importance than text matter; *how* should take precedence over *what*. A receptive attitude on the part of the men to be trained, he emphasized, is absolutely essential before training can be effective, and leadership acceptable to the men to be trained is another primary requisite. Mr. Ruthenburg expressed the

view that the training program should be actively sponsored by the highest official whom the foremen recognize as a practical manufacturing man. He stressed the need for having every principle that is discussed illustrated by an example drawn from practice with which the foreman has had intimate experience, as abstract ideas are not readily absorbed unless they are very concretely illustrated.

Foreman training, according to Mr. Ruthenburg, should be a continuous, progressive process. If the preparatory work has been properly done and the courses properly conducted, the foremen will be so desirous of proceeding that they will not allow the management to stop. A certain intellectual curiosity will be built up on the part of the group, and they will want to know what comes next. The speaker told about a course that was given in one plant, followed by a second year's course, which in turn was followed by a third year's course in which the men set up a dummy corporation for the purpose of studying it. In this way they came to appreciate the complexity of business more than would otherwise have been possible.

Who Shall Do the Training?

In the discussion that followed the papers, Norman G. Shidle, of *Automotive Industries*, called attention to the point on which Messrs. Jones and Ruthenburg had differed, namely, the matter of the source from which to obtain a man to conduct the training. Mr. Shidle felt that if it were necessary to have a leader come from outside, one of the biggest potential opportunities of foreman training would be lost and, further, that if the foremen in a plant look with suspicion upon ideas coming from executives, something must be basically wrong. He believed that foreman training should be a mutual matter between management and foremen, and expressed the view that any management ought to be able to derive an appreciable benefit from giving a course, as it would afford them an opportunity to find out what the foremen are thinking, how they are approaching their problems and the like. In studying a problem like foreman training, he believed that the management should take the initiative and do the job but that they should try to get the foremen's point of view.

L. W. Wallace, executive secretary of American Engineering Council, said that the foreman is the weakest link in the chain of industrial organization and that, until that link is strengthened, American industry will continue to suffer much waste and loss. He agreed with Mr. Shidle's statement relative to the suspicious attitude of foremen to management and said that in his opinion no reason existed for such suspicion that an executive could not take hold of foreman training and carry it through to a successful conclusion.

W. W. Nichols, of D. P. Brown & Co., stressed a point that had been brought out by Mrs. Gilbreth, namely, the fact that results will be better if reasons for doing a thing in a certain way are explained to the men receiving instruction. He also referred to Mr. Ruthenburg's remarks about other departments in a plant that have contact with and influence upon

W. W. Nichols

Eugene Bouton

a foreman's work, and expressed the opinion that it would be a good idea for prospective foremen to serve for a time in each of those departments.

Roy Bundy, of the Cleveland Trade Schools, told of his experience in a plant where a course of training was given by a member of the Board of Education. He believed that an outsider could often get things across to the men better than the management could.

Chapin Hoskins, of *Factory*, stated that whether a course of training should be given by an outsider or by one of the management would depend upon conditions in the particular factory.

Eugene Bouton, of the Chandler Motor Car Co., emphasized the idea brought out in Mr. Jones' paper that a course of training must be based on conditions in a certain plant and must be directly applicable to that plant. He also was favorably impressed with the term, foremen's conferences. Stating that the biggest problem in connection with foremen's conferences was the selection of a teacher, he asserted that foremen like to be taught by someone with a record as a successful foreman. He did not entirely agree with Mr. Wallace's statement that the foreman is the weakest link in the chain of industry, as he believes the sales department has been the most neglected of any.

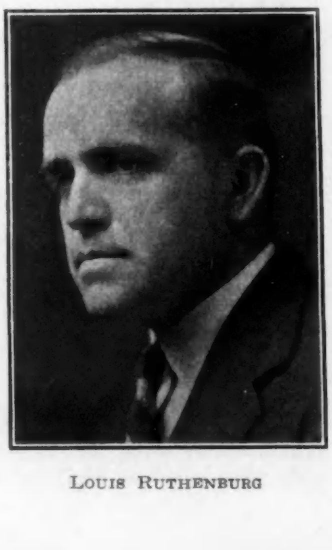
R. R. Potter, of the Shakespeare Co., felt, with reference to the question of the selection of a leader, that the whole question hinged on Mr. Ruthenburg's statement as to the necessity of inducing a spirit of receptiveness on the part of the foremen with regard to the training. He called it a matter of salesmanship and stated further that although the executives in the company are probably good organizers they are rarely good salesmen. That is one reason, he stated, why an outsider might successfully conduct a training course when a man inside the organization might fail.

Mrs. Gilbreth agreed with Mr. Ruthenburg that an important executive should sponsor the training and she also agreed with Mr. Potter that the inducing of a receptive attitude on the part of the foremen was a matter of salesmanship. She suggested the possibility of having someone from the outside start the course and get the proper attitude but believed that a person inside the organization would be needed for the actual demonstration. As to the teaching itself, she stated, a trained teacher is needed, as very few untrained people know about the teaching and the learning process.

Chairman Younger emphasized Mrs. Gilbreth's idea of presenting the training in such a way that the worker receiving the training would, in some measure, work with the teacher and thus receive a greater benefit from the teaching by actual participation in it.

Mr. Ruthenburg reiterated his viewpoint about leadership in the training course, stating that, as one of the greatest assets in an industrial organization is solidarity, he would for that reason hesitate to bring in an outside teacher except as an incidental contributor to class work. If a feeling of schism exists between management and foremen, he continued, the thing to do is to try to break down that feeling,

L. W. Wallace



Louis Ruthenburg

postponing the course until the men are ready for it. In this connection he cited a case where such resistance existed, 3 years being required to eradicate it. He said that if it becomes necessary to go outside the organization to find a man to conduct the training, let him be one of the organization when he starts teaching. An occasional outside speaker is necessary, he believed, but such a speaker should come in under the auspices of the organization.

Mr. Jones felt that, in the matter of an "outside" or an "inside" teacher, no serious difference of opinion exists. He reiterated his statement that the foremen are naturally suspicious of the management and that it does not strengthen the executives with the men to have one of the management try to do the teaching, but said in conclusion that the matter of selecting a teacher is after all not so important as the main issue, that is, the necessity for foreman training, upon which fortunately all seemed to be in perfect accord.

ENTHUSIASM PREVAILS AT GEAR SESSION

No Panacea Recommended, But Interesting Material Brought Out in Papers

The telling of experiences, the offering of suggestions, the enumerating of difficulties, and the raising of questions were important features of the Gear-Production Session, which convened in the Rainbow Room of Hotel Winton, Tuesday, Sept. 15, at 9:30 a.m. No one claimed to have solved the gear problem, but the session was just as profitable as if such a claim had been made, as two splendid papers were presented and an interesting discussion followed each paper.

Gear Troubles and Some Suggested Remedies

Some of the usual troubles in supplying gears were mentioned by Perry L. Tenney, of the Muncie products division, General Motors Corporation, who related the experiences of his company in the last 2 or 3 years in overcoming these troubles. His paper, entitled Coordinating Designs and Production Methods in Gear Development, is printed in full in this issue of The Journal.

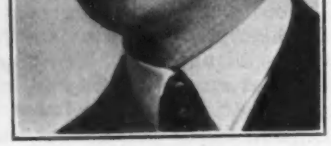
Mr. Tenney spoke of the periodic recurrence of problems of gear noise and wear that apparently arise from no specific cause, and told most interestingly about a thorough analysis that was made in an effort to assign a cause to the trouble and to prescribe a remedy. In the attempt to find exactly what was wrong, all loyalty to established practice was abandoned, and consideration was given to materials, process, design, and the like as if nothing were known on these points. Tests were made to determine the best steel to be used and the best treatment for that steel, special attention being paid to the cyanide hardening of the steels. The conclusion reached was that very little difference was apparent in the performance of any of the steels with normal treatment; the two outstanding features were the high wear-value of cyanide-treated chrome-steel, and the still better value of chrome-vanadium steel when cyanide treated.

The tests gave the basis for probably the most vital information required for motor-car transmission design, namely, the ratio of dynamometer hours to thousands of miles of field operation of the car. All figures indicated a safe average of 3000 miles of car use per hour of dynamometer test in intermediate gear.

Some experiences on gear-tooth grinding formed an interesting part of the paper, and the conclusion derived from these experiences and the others already mentioned is that real progress is attainable only through coordinated activities, that is, through coordinating all branches behind each step in any given procedure.

Past-President Alden, chairman of the session, expressed the opinion that the entire mathematical basis of gears is wrong. He alluded to work that is being done in this connection and believed that some very definite and helpful results would soon be ready for presentation. His view is that with a proper mathematical basis for designing gears and with adequate watching of each step in gear manufacturing, it makes very little difference what steel is used.

P. L. Tenney



R. S. Drummond

Cyanide Hardening Discussed

Questions were asked relative to pitting, as a remedy for which one company advocated increasing the tooth face. Mr. Tenney stated that his company had at one time made carburized gears but had ceased to do so under commercial pressure. Pitting had been encountered but it was of a different nature from the pitting of the high-carbon gear. Cyanide hardening was believed to be efficacious in reducing this trouble, though Mr. Tenney felt that tooth form had about three times as much to do with it as the hardening process.

The use of plain bearings to secure better mountings for gears was discussed, and Mr. Tenney stated that plain bearings have been found unsatisfactory, especially under high pressure, and the trend is therefore away from them.

Grinding, it was brought out in the discussion, lengthens the life of the electric-furnace and the oil-hardened gears, but cuts down the life of the cyanided gears, and in this connection the general effects of cyanide treatment of steel were considered. When the steel has been cyanide-treated, the cyanide penetrates the steel from 0.003 to 0.005 in.; just what this penetration amounts to in the life of the gear is not known.

Asked whether the clash ends of cyanide-hardened gears wear well, Mr. Tenney replied that no difference is found between cyanided gears and those that have been given other treatment, except that the former have a very hard surface. They are sometimes so hard as to suffer upsetting from clashing rather than show surface abrasion. Considerable needs to be done in the way of chamfering to see that the points of clash are far enough away from the surface to prevent surface abrasions or upsetting from changing the tooth form.

In the cyanide treatment, a 45-per cent sodium cyanide bath is used. It is necessary that the cyanide remain above 3 per cent. A 10-per cent solution was tried, in the belief that this allowed a sufficient margin, but it was found inadequate, and 45 per cent is necessary for the sake of safety.

A member asked whether any nitrogen-iron combination was formed in the cyanide treatment, and Mr. Tenney replied that thus far in his experience no effects of nitrogen have been found.

Relative to the effect of cyaniding on gear noise, Mr. Tenney said that it is difficult to make an authoritative statement in this regard, since gear noises have at times been attributed to cyaniding, whereas on other occasions the cyanide treatment has been used in an effort to render the gears more nearly quiet.

True and modified forms of tooth were discussed, and Mr. Tenney felt that it is best to stick as closely as possible to the true involute form of tooth.

Replying to a question as to the engine speeds used in the dynamometer tests, Mr. Tenney stated that the dynamometer tests were based on 90 ft-lb. of torque at 1700 r.p.m.

EARLE BUCKINGHAM

C. H. LOGUE

R. S. Drummond, of the Gear Grinding Machine Co., who was asked to make a few remarks relative to the length of gear teeth, stated that the trend is toward longer teeth.

THE PROBLEM OF GEAR PRODUCTION

Earle Buckingham, of the Niles-Bement-Pond Co., who presented the other paper on the program, stressed the fact that gear production offers a troublesome problem that is far from being solved, and he mentioned at the start that his main purpose was to excite an argument. The paper is printed in full in this issue of THE JOURNAL. Mr. Buckingham emphasized the desirability of having suitable means for detecting and measuring errors, and spoke of the need for instruments that are simple, rapid and effective, as contrasted with delicate laboratory-instruments that are not adapted to usage in production work. He told about machining processes and described briefly a burnishing process that smooths the profiles of machined gears by crowding them into accurate hardened-and-ground burnishing gears. Mention was made of the difficulty, inherent in any production problem, that is due to the difference in the workmen who operate the production equipment.

Chairman Alden called attention to the importance of what Mr. Buckingham had said about the need for simple measuring instruments and asked Mr. Drummond to speak about some recent developments in this field. Mr. Drummond described briefly a gear-tooth measuring-machine that has been used, with rather remarkable results, not only in connection with spur gears, but on a number of timing-gears, on spiral gears, on bevel gears, and in a few instances on spiral-bevel gears. He described also a comparing device that makes it possible to check a gear tooth in 13 sec.

The importance of the accurate mounting of gears was stressed by Chairman Alden, who stated that no small amount of wear and noise results from not putting gears together as they were intended to be.

A question relative to the roll-test was answered by Mr. Drummond, who, calling it by its other name, the "jiggle" test, stated that he has no confidence in it because it merely shows that something is wrong without indicating the nature of the trouble.

Attention was then given to a matter of nomenclature. It was asked whether it would not be well to attempt to eliminate the term, spiral gear, when helical gear or screw gear is meant. Mr. Buckingham replied that the term is a misnomer except in the case of bevel gears. Helical gears used to drive shafts at an angle are usually called spiral gears, either merely from usage or from an effort to avoid the periphrasis, although this use is technically incorrect.

Long addenda gears were discussed with special reference to the comparative difficulty of cutting them. Mr. Buckingham believed that the difficulty in cutting such gears is more mental than practical, as it may require some harder thinking.

Mr. Tenney stated that the only difficulty connected with work on modified teeth is that, after a certain range of a so-called standard hob is passed, it is necessary to use a special cutter. Mr. Tenney criticized the use of the interchangeable gear system in transmissions, stating that no basic reason exists for the use of this system and that it is, in fact, detrimental.

An interesting feature of this lively session was the description by Charles Logue, consulting engineer, of some experiments made by him relative to the mathematical basis of gear design, together with a statement of the conclusions drawn from the experiments.

MACHINE-TOOL SESSION

Speakers Outline Needs of the Industry in Tool Selection and Application

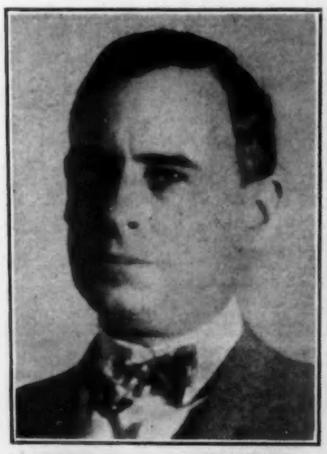
At the machine-tool session, held on Tuesday afternoon, R. M. Hidey, of the White Motor Co., gave a paper on the machine-tool needs of the automotive industry. This was supplemented by papers by W. G. Careins, of the Ajax Motors Co., on the selection of machine tools, and by R. M. Anderson, of the Holley Carbureter Co., setting forth the practice followed in the production of carbureters for Ford cars and for Fordson tractors. The paper by Mr. Careins was of unusual interest, as his company has recently installed a very large number of machine tools. Mr. Hidey's paper is printed in full in this issue of THE JOURNAL.

It is believed that future developments will establish the fact that the presentation of Mr. Hidey's paper and the discussion of it, as well as of Mr. Careins' paper, constituted an event of much historical importance with regard to cooperative and standardization procedure in the machine-tool field and in that field and the automotive field jointly.

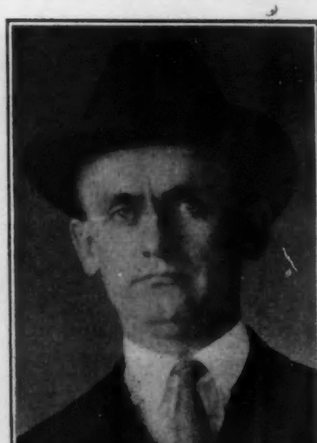
In opening the session, Chairman Eugene Bouton, after stating that cooperation between engineers, production men and machine-tool builders was never needed so much before, said that truly remarkable developments in production methods have been introduced in the last few years.

Mr. Hidey deliberately and effectively precipitated an incisive discussion of the fundamental needs of the industry with respect to machine tools and conditions surrounding their development, acquirement, and use. His specific recommendations were that

(1) Multi-purpose machines capable of using special tool equipment adapted to quick change-overs should be developed
(2) All machines should be safeguarded so that they can be put into immediate use after purchase without further expenditure by the purchaser
(3) All moving parts should be balanced so that vibration of the tools will be reduced to the minimum
(4) Continuing cooperation with the automotive industry, the machine-tool firms should freely



A. C. COOK



R. M. HIDEY

interchange with each other new ideas and developments for the benefit of their industry

(5) The machine-tool industry should analyze the needs of the automotive industry for the future, so that dependence on replacement orders may give way to actual production for analyzed needs

Standard Vesus Special Machine-Tools

In the discussion, Vice-President A. C. Cook, of the Warner & Swasey Co., said that the machine-tool builders had added to the tools a number of important features as a result of information acquired from the automotive industry. He confirmed Mr. Hidey's statement that standard machine tools are more profitable in the automotive industry than are those of special type, and added that single-purpose machines are economical only when used for immense production. The bread-and-butter tools of the machine-tool industry are the standard types. With regard to the apparent lack of cooperation in the tool industry, Mr. Cook stated that the diversified products of that industry make cooperation in it more difficult than in the automotive industry. The only problem that is common to the various groups of toolmakers that are members of the National Machine Tool Builders' Association, is that of forming or cutting metal. Not many years ago the entire industry was revolutionized by the sudden introduction of high-speed steel. Machine-tool design has been improved materially in the last 5 years. In connection with Mr. Hidey's allegation that machine tools are sold before they are sufficiently developed, Mr. Cook thought that the majority of machine-tool builders experiment long and carefully with their new products before placing them on the market. As to standardization of machine tools in general, Mr. Cook pointed out that this is a knotty problem. Some effort in the direction of solving this is being made. Recognizing the value of standard data sheets, various companies use the form of sheet that was prepared by A. L. Evans and adopted by the National Machine Tool Builders' Association for giving reference information to use when new tools and jigs are to be made.

General Manager DuBrul, of the National Machine Tool Builders' Association, discussed very frankly the points Mr. Hidey made. He protested that the latter had generalized too much in the very good paper he read. To this Mr. Hidey replied that in bringing about the discussion resulting from his paper he had accomplished what he desired. He freely acknowledged that he had dealt in some generalities.

Mr. DuBrul said that no kind of machine tool had ever been produced in large quantities and that it is impossible to produce any machine tool in such manner. He raised the question whether, for the purpose of satisfying its needs from the machine-tool industry, the automotive industry had been willing to pay adequate prices. Referring to a quotation from some of Mr. DuBrul's remarks in Mr. Hidey's paper, the former asserted that the machine-tool industry does not live on replacement orders, but on orders for new designs. The life of the machine being so long, the industry would starve if it depended on replacement demand. Mr. DuBrul dismissed the matter of the single-purpose machine as being purely one of economics. Very few single-purpose machines are built.

E. F. DuBrul

W. G. Careins

As to equipping machine tools in general with safety guards, it was pointed out that conflicting laws exist in the different States and that as yet no comprehensive digest of the State laws on the subject had been made.

As to the interchange of shop information between machine-tool builders. Mr. DuBrul expressed the opinion that no adverse criticism could be offered on this score. He said that he knew of no shop to which access was denied competitors. However, he welcomed the suggestion that the machine-tool builders cooperate more with each other, stating that at the present time the cost of the experimental and research work they do now severally is excessive. In any event, however, the cost of production must be borne by the customer.

On the subject of dissatisfaction with the performance of machine tools "guaranteed" to do certain work, Mr. DuBrul argued for integrity in selling and for the training and employment of well-qualified salesmen, as well as for intelligence in purchasing. He deplored the lack of competent salesmen in the machine-tool field, attributing this to the fact that the industry cannot afford them.

Mr. DuBrul expressed his belief in standards. He observed that it is idiotic to maintain the present 57 varieties of vertical drilling-machine. He blamed buyers for such a condition, asseverating what has been said before, namely, that when buyers insist on standardization they will get it.

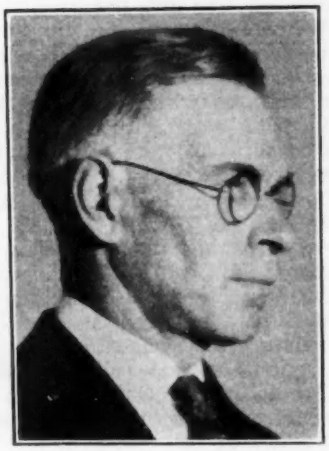
Selection of Machine Tools

In taking up the general subject of the considerations involved in the selecting of machine tools for installation in an automotive plant, Mr. Careins remarked that, if five different persons were asked to purchase a 16-in. lathe for identically the same job, it is not improbable that each would specify a different make of lathe and according to his view have a good logical reason for the selection. In the paper the author's purpose was to analyze some of the more concrete factors involved in selecting machine equipment. He defined three types of use of machine tools as (*a*) in plants having a variety of products with little duplication, in maintenance and tool departments of production shops, and in small job-shops; (*b*) in shops of fairly large production of an article subject to frequent changes in design, seasonable demand, or other condition preventing long-settled manufacture; and (*c*) in plants engaged in large and intensive production of a standardized article subject to very little design change from year to year, quality standards and production methods having been well established.

In (*a*) tools of the widest possible range of usefulness, size and type are required. In (*b*) the demand on the machine tools is not so diversified, but the equipment must be somewhat flexible. The equipment consists largely of standard machines specially tooled, with an occasional single-purpose machine. In (*c*) are found many machines of special design capable of large continuous production, the equipment being largely automatic or semi-automatic; also standard machine tools stripped of all attachments not necessary to do the immediate work in hand. The machines are arranged so that one operator can take care of two or more of them. In some cases the machines are substantially integral parts of a combined automatic and conveying system that takes raw material at one end and delivers a finished article at the other.

Very careful consideration must be given to the method of machining to be used, the inspection tolerances and the quality of finish required. Possible obsolescence of special machines or of expensive tooling as a result of a change in the design of the product should be investigated in advance. Parts such as manifolds and brake rigging have been subject to frequent design changes. In estimating the cost of

E. P. BLANCHARD



R. M. ANDERSON

producing a part on a special machine, the depreciation factor should be approximately twice that for a standard machine. A higher maintenance charge also should be made.

Generally speaking, a special machine cannot be designed, built, delivered and put into successful operation in less than 3 months. In the case of special machines, the purchaser should furnish the machine-tool builder with a statement of the desired characteristics of the machine, indicating the points of location, the production per hour required, the method of handling the work, the surfaces to be machined, the work that has been performed in previous operations, the hardness of the material and any available data as to feeds and speeds. What the purchaser wants is guaranteed production at a definite cost, including a complete analysis of the operations, the production to be expected under standard conditions, the quality of work securable, and the tooling recommended. Quotations received on this basis can be checked and compared.

Knowing the production ability, the cost and the reliability of a machine, the cost of the work to be done can be estimated closely, as the direct labor-cost can be based on prevailing labor-rates and the number of pieces produced per unit of time, the fixed overhead to be charged to the machine being determined largely by the estimated life of the machine, the repairs, and the original cost. Life and maintenance cost must be determined empirically. Some firms prefer securing a reasonable length of life with the minimum of repairs, while others accept a higher maintenance cost to secure maximum service from the equipment before it is discarded.

Mr. Careins said that some machines on the market today require so much waste effort on the part of the operator that the capacity of the machines is not nearly fully utilized. Many machines are first-class in every respect except that they include inadequate countershafts. Also at times the direct-drive motor mounting was apparently an afterthought so far as design is concerned. Again, driving pulleys of insufficient width are incorporated. Nothing is so exasperating in the machine shop as pumps that have to be primed after a machine has been idle for some time, or that do not have sufficient capacity at all speeds. Mr. Careins said that cast-iron gears in the head or feed mechanism are almost always troublesome; the same thing is true of cast-iron cams and levers.

Many builders still design machines with a large number of oil cups or holes, instead of providing for the lubricating of all parts of the machine from a central point so far as possible. Mr. Careins said that as many repairs are necessitated by a lack of lubrication as by wear or accident.

Greater accessibility to parts in making repairs is urgently needed. Frequently it is necessary to dismantle a machine almost completely to make a minor repair or adjustment.

E. P. Blanchard, of the Bullard Machine Tool Co., mentioned a machine tool that, although it is used only 3 months per year, is worthwhile as a labor-saver. In connection with tools for job shops or production shops, the determining thing is not the number produced in a given time, but relative quantity—a matter of margin of cost of the new process as compared with the old. Mr. Blanchard urged that the automotive manufacturers develop and standardize those features of tools which they want and then determine upon the application of machine tools that is to be made by a scoring of points.

Mr. Blanchard also recited the case of the building of a tool for a special purpose, using therefor parts of standard machines. Although the user did not need all of the feeds and attachments that were combined in the machine, the machine would have cost more if built from special parts.

In conclusion, he expressed hope for more cooperation and mutual confidence and frankness between machine-tool builders and between them as an industry and representatives of other industries, upon matters relating to cost and to facts in general.

PRODUCTION OF FORD CARBURETER

Mr. Anderson showed lantern slides of the two lines of vertical drilling-machines upon which the Ford carbureters are machined. The carbureter was designed so that its fabrication would permit of simple drilling operation without use of multiple spindles. The machines are all placed in continuous line on cast-iron table construction and not more than seven spindles are driven from one motor.

The balancing of the lines so that castings would not pile up at any point was necessary. Deciding upon a suitable method for smooth operation involved considerable study. At some points on the line small holes have to be drilled accurately.

All of the fixtures are bolted directly to the bed so that it is impossible to change their position relatively to the tools. The feeders on the presses are automatic. Consequently, 10 men can supervise the required number of operations with the 34 spindles.

The Ford carbureter is of course made in enormous quantities and must be made well and at small cost.

HEART-TO-HEART EXPERIENCE TALK

K. T. Keller Brings Convincing and Helpful Message to Production Dinner

Out of his long experience in the automotive production field, K. T. Keller, vice-president and general manager of General Motors of Canada, Ltd., gave a most convincing and helpful message to the 200 members and guests whom President Horning welcomed at the Production Dinner at the Hotel Winton on Sept. 15.

Dividing production into the three major divisions of quality, quantity and cost, Mr. Keller reiterated his opinion that quality is the prime feature of an automobile; quality is first, because without a sound product an enduring business is impossible. Referring to the earliest days of the automobile

H. L. HORNING

K. T. KELLER

industry in this Country, the speaker stated that, while the chassis is the finest piece of development we know, and the automobile body has "come along," much still remains to be done to improve the major structural elements. The securing of quality is a matter of discipline. The maker must know what he wishes to produce and what he expects the product to do.

Mr. Keller made a strong plea that the workman be given the best possible opportunities to carry out his duties. His teammate, the inspector, is the customer's protector and should be the best man available. Quantity also is a matter of organization. Machine-tool capacity is relatively easy to estimate. The important thing is looking ahead with an eye to quick economical production. The one thing that controls the output of an assembly line is getting the material to that line.

A great many cost figures are not understandable, but an executive can secure helpful figures if he knows, and will state, what he wants. The controllable cost element is overhead. Mr. Keller felt that the average plant that runs with an overhead of 150 per cent is doing a good job. He has operated plants as low as 87 per cent. In general, percentage figures for overhead mean nothing. Properly, overhead should involve, What is each man doing for the money he is getting? Too many men creep into overhead who should not have gone from production.

In general, Mr. Keller is of the opinion that an executive should learn as much as he can before he becomes too old and too much burdened with responsibilities; it does no harm to move from plant to plant, provided knowledge is acquired in the proceeding. It is a prime function of the executive to develop his men to the limit. Mr. Keller has a tender place in his heart for the young men, but made it clear that on purely utilitarian grounds the young men must be developed intensively for the industry. In his company each year six young men of superior intelligence and good breeding are started on a 2-year training course.

Mr. Keller was very felicitous in expressing his gratitude to the many men in the industry who had assisted him in his progress; several of these men attended the dinner. In all, he gave very sound sensible advice based on many forms of experience in the field of automotive production.

Mr. Keller's address will appear in full in a later issue of THE JOURNAL.

STANDARDIZED JIGS AND FIXTURES

Their Use Effects Large Savings at Cleveland Plant in Machining Engine Blocks

J. Gustaf Moohl, of the Cleveland Automobile Co., stated in his paper entitled Applying Jigs and Fixtures to Engine-Block Machining, printed elsewhere in this issue of THE JOURNAL, that by slight changes the same patterns can be used for different jigs at an appreciable saving. He emphasized the importance of suitable design and construction of jigs and fixtures, which calls for close cooperation between the engineering department and the toolroom engineers.

J. GUSTAF MOOHL

JOSEPH LANNEN

Mr. Moohl showed how heavy sections should be properly distributed with a view to obtaining adequate rigidity and insuring satisfactory service. The jigs and fixtures under consideration were those that applied to the machining of engine blocks.

DISCUSSION ELICITS DESCRIPTIONS OF OTHER TYPES

In opening the discussion of Mr. Moohl's paper, Chairman John Younger, of the Ohio State University, described briefly some of the very simple and crude jigs and fixtures that were used years ago. He believed that the design of a fixture is as important as the design of a machine tool.

Attention was called by Chairman Younger and W. L. Carver, of the Chilton Class Journal Co., to the necessity of distributing the weight properly to warrant adequate rigidity of the fixture.

F. E. Cardullo, of the G. A. Gray Co., described briefly a rotating, six-sided fixture, with holes properly placed on each of the six sides to allow for manipulation with a device of the ice-tong type. He called attention to the fact that the choice of jigs depends upon the number of pieces required.

Mr. Moohl stated in reply to a question from R. I. Mowry, of the Studebaker Corporation of America, that the dowel holes should be made as large in diameter as possible, 1 or 1¼-holes being better than those of smaller dimensions.

Eugene Bouton, of the Chandler Motor Car Co., stated his belief that in the design of jigs and fixtures too little attention is often paid to the question of time required for loading, unloading and freeing from chips. He stated that these operations in many cases require more time than does the actual machining of the parts. The rapidity of clamping, unclamping and freeing from chips is an important consideration.

STANDARDIZATION RECOMMENDED

Replying to an inquiry from Chairman Younger, Mr. Moohl stated that jigs and fixtures may well be standardized in a particular shop; he thought a great saving could thus be effected. He added that some eight or nine fixtures can be made from the same patterns in certain cases.

J. Lannen, of the Paige Detroit Motor Car Co., described briefly three types of cam that have been standardized for use on some 90 per cent of the jigs and fixtures in his plant. One of these types is a cam 2⅛ in. in diameter, with a ⅛ in. offset. The box cam, he said, is well adapted for the automatic opening of a slide by the rotation of the cam in the slide. The use of the tumble type of jig has been largely eliminated. Mr. Lannen stated that troubles in the cam are more often the fault of the tool designer than of the cam itself, and he thought many prejudices against cams would be removed were the designs properly made. He cited an example where the average life of the cam is 5 years, and stated his belief that with proper design the question of upkeep should be negligible.

In answer to a question from F. E. Cardullo, Mr. Moohl stated that it is necessary to conduct a careful time-study to determine when the tumble type of jig should be eliminated in favor of other types, as determined by the number of pieces required.

MAKING MACHINE TOOLS SAFE

Thalner Asserts Accidents Are Unnecessary and Shows How to Reduce Their Number

Prefacing his remarks by the statement that the time has passed when accidents in industry were considered necessary, R. F. Thalner, of the Buick Motor Co., asserted his belief that the application of safety methods throughout automobile plants is a necessity demanded by both humanitarian and economic considerations. After reviewing briefly the history of the safety movement, the speaker cited the example of the Buick Motor Co., which is still young in this work, where the accidents have been reduced from 1746 in

1923 to 726 in 1924 and to 287 for the first 6 months of 1925. He believed that the appalling number of accidents that occur yearly throughout the United States is due largely to the great demand for increased production and maximum speed of accomplishing various operations.

Proper Tools and Education

By the use of proper tools many hazards may be avoided. It is necessary, however, to accompany the improvement of tools by suitable education of the operators. In certain cases where it is impossible to make a tool entirely safe by its original design, it is necessary to resort to suitable methods of guarding. It is also essential that operators observe certain fundamental rules. For example, it must be standard practice for a man working on a vertical drilling-machine never to wear gloves or long sleeves. In removing the chips from a milling machine, a source of many accidents, a brush, stick or similar device should be used in preference to the workman's hand. Belts and gears should always be covered. Tools should be properly ground to eliminate the possibility of injury from chips or shavings. The use of goggles is often advantageous, but should be resorted to only in cases where protection cannot be otherwise provided, inasmuch as the wearing of goggles becomes uncomfortable to the workman.

Punch presses have been made safe by the use of sweep guards, tell-tale gates and devices that harness the hands of the operator, but in spite of all these provisions considerable intelligence is required of the operator.

Mr. Thalner stated that a man who operates a machine while in constant fear of injury cannot accomplish his work most efficiently. A large number of examples of tools made safe were cited and illustrations were shown. Among the most interesting of the latter were those applying to shock tools, such as chisels, stamps, drills, drifts, punches and plugging tools that show a mushrooming effect after use.

Hammers Made Safe

One might consider the ordinary hammer a safe tool, but many accidents have occurred from its use, and Mr. Thalner gave an account of the steps that have been taken to prevent such accidents. To make the hammer safe from the flying-nail hazard that results from striking the nail a glancing blow, a special type of head having a number of annular grooves in the face has been used. Considerable care must be exercised in the proper hardening of these hammers and in their balancing. An improperly balanced tool fatigues the workman quickly and is thus uneconomical.

In conclusion, Mr. Thalner reiterated the statement that accidents "do not just happen." The causes for these accidents that cost money which cannot be absorbed in the overhead, since they are unnecessary and preventable, are very definite.

Safety Measures Discussed

E. F. DuBrul, of the National Machine Tool Builders' Association, advocated the promulgation of uniform safety codes in all States, and mentioned the work now being carried on by a sectional committee that is operating under the procedure of the American Engineering Standards Committee. He stated that casualty companies lack detailed statistics to indicate at which part of the tool accidents originate. He emphasized the difficulty involved in educating employes to the necessity of using safety devices after they have once been installed. Factory inspection, he said, should be removed from politics, and well-trained, experienced safety engineers should carry on the inspection. He believed that the various companies should become more interested in this matter of inspection and they should encourage its satisfactory functioning.

W. G. Careins, of the Ajax Motors Co., stated that the individual motor drive has been an important factor in accident prevention. In reply to Mr. Careins' question, the speaker stated that board hammers are made safe by the installation of a cap, fully enclosing the stroke of the hammer. A screen guard is also placed over the operator to prevent his being struck by the board. Breaking of steam cylinders on steam hammers is avoided by the use of an expansion pot at the upper end of the piston.


B. B. Bachman


R. F. Thalner

B. B. Bachman, of the Autocar Co., spoke briefly of the hazards involved in work carried on in the engineering or experimental departments, where a large variety of difficulties is involved and great hazards result. He believed that in this case education is of prime importance, inasmuch as the safety or lack of it must depend largely upon individual judgment.

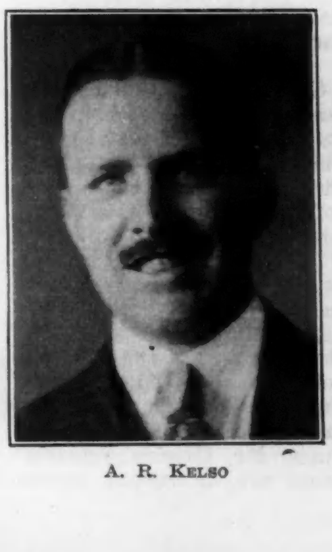
Russell Hoopes, of Hoopes Bros. & Darlington, Inc., stated that oftentimes inspectors who have been chosen on a basis of political considerations, rather than ability, choose the least vital points as the most important. Mr. Thalner replied that the ordinary type of inspector finds greater interest in the application of belt guards, for example, when, as a matter of fact, less danger exists in this case than at other points that are often overlooked.

MACHINE-TOOL MAINTENANCE ANALYZED

Facts and Statistical Data Are Invaluable Aids in Estimating Tool Values

Statistical analysis of machine-tool repairs may be effectively used as a basis for machine-tool selection. This procedure has been used by A. R. Kelso, of the Continental Motors Corporation, whose excellent paper entitled The Analysis of Machine-Tool Maintenance was presented in the absence of Mr. Kelso by Chairman John Younger, of the Ohio State University and *Automotive Abstracts*. The paper is printed elsewhere in this issue of The Journal.

Machine repair analysis and a criticism of present-day equipment with analytical tables based on data collected


A. R. Kelso


F. E. Cardullo


R. E. Miller
The Iron Age


N. G. Shidle
Automotive Industries


F. H. Colvin
American Machinist


Erik Oberg
Machinery

FOUR OF THE MEMBERS OF THE "FOURTH ESTATE" WHO WERE PRESENT

from an extensive study were related in the paper of Mr. Kelso.

MAINTENANCE REPORTS USED

Eight types of common machine tools were considered and the maintenance advantage of one over the other was deduced from the consolidated tables based on monthly reports. A comparison of each class of machine tool with the others was made and a summary of the weaknesses of each class, as based on the frequency of repairs of the elementary parts, was included. The attention of machine-tool builders was drawn to the conditions that the shop encounters with the equipment.

A maintenance budget system was described as it has been applied in one plant to provide comparative data pertaining to certain equipment that is running in excess of budget time. This system also was said to serve as an inspection of the conditions of the equipment and as an indication of the time when overhauling should be done.

Mr. Kelso concluded that a few predominating makes of machine in each group can profitably serve as a basis for standardization. The remainder of the makes, in comparison, are not providing the same return on the investment, owing to the greater expense charges and the loss of time for maintenance.

WHAT THE DISCUSSION BROUGHT FORTH

E. F. DuBrul, of the National Machine Tool Builders' Association, in commenting favorably upon Mr. Kelso's paper, mentioned the wisdom of obtaining facts from statistics to enable the buyer to choose his tools according to superiority rather than on the basis of guesswork and favoritism. He believed that a system of rating machine tools could well be established along the lines of the systems used by fire insurance companies in establishing risks. It is important, he said, to have the data procured by persons possessing ability in statistical work.

F. E. Cardullo of the G. A. Gray Co., felt that cooperation between the tool builder and user would develop very rapidly in cases where real facts are used in place of guesswork. He believed that, in the last analysis, the buyer must furnish the laboratory for the development of machine tools best adapted to the fulfillment of specific needs. He wished that Mr. Kelso could elaborate his paper so as to show the causes for repairs.

Mr. Cardullo was surprised at the high cost of rebuilding in certain cases mentioned in the paper. He felt that something, perhaps the maintenance system, must be wrong when the rebuilding cost rises to one-half the cost of the new tool.

W. G. Careins, of the Ajax Motors Co., believed that, from an economic standpoint, a machine tool should be returned to the maker when complete overhauling becomes necessary.

Mr. DuBrul, in commenting upon Mr. Careins' remarks, stated that the machine-tool shops are, in reality, super-jobbing shops rather than production organizations. He stated that the rebuilding of machine tools is at times undertaken by companies during dull seasons, but that this practice does not extend into periods when the demand for new tools is great. He believed that the rebuilding of tools may create a disadvantageous commercial situation at times.

In concluding his remarks, Mr. DuBrul asserted that as yet no satisfactory solution has been found for the rebuilding problem. He knew of no company that makes a regular practice of rebuilding. An important factor in this connection is the lack of well-trained machinists. Mr. DuBrul asserted that the users of machine tools can best satisfy their own interests and those of the builders by forecasting their demands in such a way as to eliminate to a large extent the great fluctuation in machine-tool demands as it now exists. He stated that machine-tool replacement is more often caused by obsolescence than by wear.

Erik Oberg, editor of *Machinery*, commented upon the criticism that had been made of the automobile industry because it expects the machine tool to pay for itself in a very short length of time. He believed that this requirement is justified owing to the rapid changes that take place in the industry. He cited an example where a milling machine, costing $9,500, was used for 1 week and then set aside for a period of 3 years when it was sold for $500.

Eugene Bouton, of the Chandler Motor Car Co., mentioned the fact that automobile plants are equipped for many types of inspection, but that no systematic inspection of machine tools has been provided. He asserted his belief that inspectors should be utilized to determine the necessity for repair before the machines reach a critical state. He stated that, in his opinion, it is not profitable to rebuild a machine tool when the cost reaches one-half that of the new equipment. He could not find facts to justify the statement that machine-tool builders cannot sell replacement parts at a profit.

INSPECTION SESSION AN ATTRACTIVE ONE

Two Interesting Papers Relating to Diverse Branches of the Industry Presented

When calling to order the Inspection Session of the Production Meeting, on the afternoon of Wednesday, Sept. 16, Chairman A. H. Frauenthal, of the Chandler Motor Car Co., spoke of this session as the first attempt made to incorporate an inspection session into the Society's Production Meeting. For some years, he stated, the inspection situation has been receiving more and more attention, and it seems desirable that a certain amount of time should be given to the subject at meetings like the Production Meeting where an outstanding feature is the liberal exchange of ideas. Chairman Frauenthal continued by saying that, as not enough

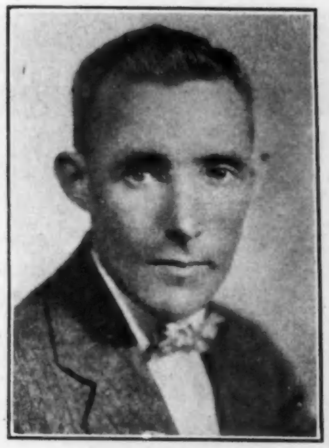
inspection men are members of the Society to make the formation of a separate branch devoted to their interests advisable, the inspection talent should be considered a part of the production membership of the Society. The advisability of having inspection sessions at future Production Meetings would, he stated, be largely determined by the success of the initial meeting, such success depending not merely upon attendance but upon the spirit in which the material was presented and received, in other words upon the amount and the nature of the discussion following the presentation of the papers.

Ratio of Productive Men to Inspectors

C. J. Ross, of the Buick Motor Co., the author of the first paper on the afternoon's program, entitled Inspection Methods, was unable to attend the meeting, and in his absence the paper was ably presented by R. B. Schenck, of the same company. This important contribution to the Production Meeting is printed in full in this issue of The Journal.

Mr. Schenck in presenting the paper started by telling about the general layout of the inspection system maintained by the company with which he is connected and followed his description with specific illustrations of various inspection operations. A consideration of the relative importance of inspection was followed by the specific statement that when the ratio of productive men to inspectors does not exceed 15 to 1, no excuse exists for failure to maintain standards. Figures were quoted showing (*a*) the total number of inspection hours per unit part produced in a given period, (*b*) the number of inspection hours per $100 worth of productive labor in the last 4 years and (*c*) the ratio of productive hours allowed to one inspection hour and the ratio at which several plants were running during a given week. Inspection operations were discussed under the following divisions: metallurgical department, crankshafts, cylinder-heads, cylinder-blocks, pistons, flywheels, connecting-rods, intake and exhaust manifolds, gearcase covers, miscellaneous parts, camshafts, Delco equipment, starting motors, assembling line, final engine inspection, transmission spline-shafts, transmission counter three-gear forging, transmission cases, differential carriers, steering-knuckles, universal-joint yokes, rear-axle assembly, chassis springs, flywheel rings, wheels and brake drums, and front axles. An interesting feature of the metallurgical inspection was the description of the spark test, a rapid method of determining chemical composition; this test, although by no means new, has only recently been adopted as a routine method of inspection on large-scale production.

The question was raised by Paul Mueller, of the Pratt & Whitney Co., as to what means are used for maintaining in a fixed state certain standards of quality that cannot be measured very well, such as transmission noise, the feeling of a car running on the road, maneuverability, and the like. He gave as his experience that, when work has been going on well, the standards of quality have crept up until, after 6 months or a year, quality that had formerly been considered good was no longer passable. Mr. Schenck replied that in his company the judging of such qualities was based mainly on personal opinion but that it was the personal opinion of experts whose experience formed the basis for a standard. He admitted, however, that such a standard would not be a fixed standard, mathematically exact, and that it would be subject to the variations mentioned by Mr. Mueller.



John J. Feeley

R. B. Schenck

Ancel St. John stressed the importance of developing devices that could measure accurately such qualities as those just mentioned. Chairman Frauenthal brought out the fact that magnitude of noise is not the only thing to be considered in measuring gear and other noises, as the objectionableness of noise depends upon other factors as well. In this connection the factor of resonance received some attention.

The Inspection of Airplane Parts

Some Aspects of Inspection in the Airplane Industry was the title of a most instructive paper, presented by John J. Feeley, of the Glenn L. Martin Co. Mr. Feeley explained briefly the different parts of the airplane, their manner of functioning and the movements necessary to control directional flight, and discussed some principles of design. The importance of cooperation between engineering and production received attention. A discussion of the relation of the contractor's inspection with the customer's inspection was followed by an explanation of the control of materials and raw stock inspection, covering methods of handling material, detecting flaws, and the like.

A noteworthy feature of this portion of the paper was Mr. Feeley's discussion of wood for aircraft. Only the very highest grade of lumber that can be obtained is used. Each shipment is furnished against rigid specifications and when

G. M. Graham

Ancel St. John

E. M. Sawyer

J. V. Whitbeck

Some Other Attendants at the Meeting

SIGN THAT ENTICED MANY INTO THE PUBLIC AUDITORIUM
The Commanding Position of This Announcement Can Be Seen in the View at the Bottom of the Page

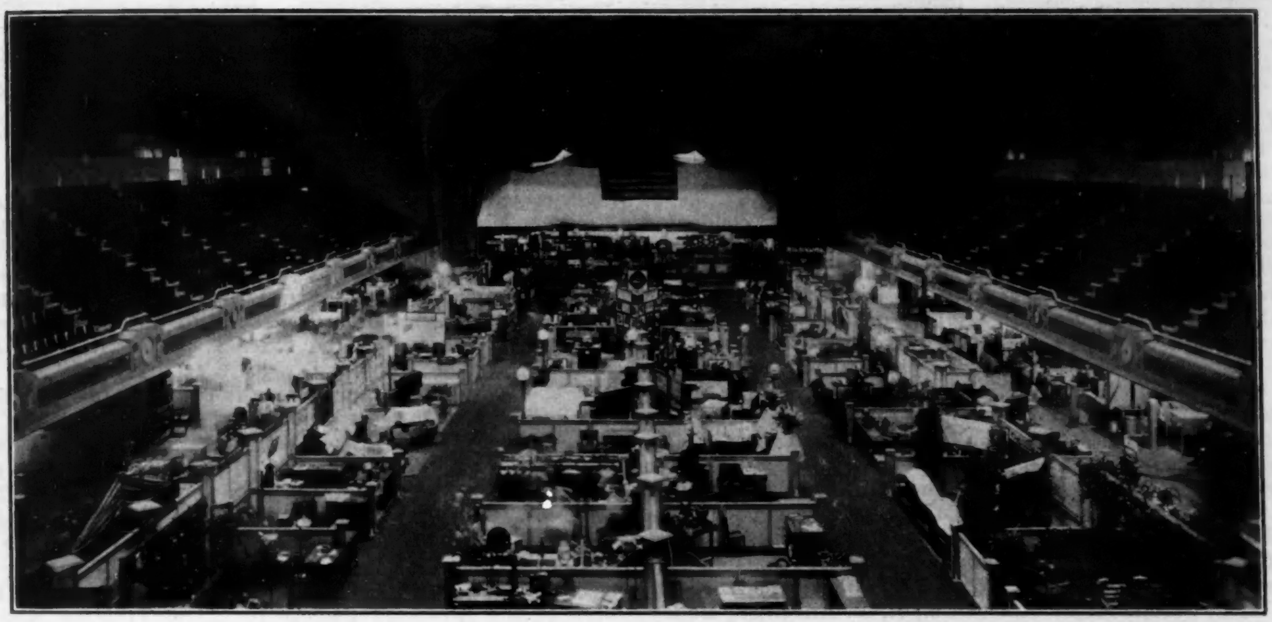
received green it is inspected on four sides by expert wood technologists. All of the wood is kiln-dried, the work being very carefully done. After this process, the wood is stored for a period of about 2 weeks under typical mill conditions. The wood is carefully inspected and selected for its various uses and great care is taken to eliminate all harmful defects. Mr. Feeley expressed the belief that the time is not far distant when wood will be to a great extent eliminated from use for structural purposes in aircraft.

Mr. Feeley made reference to inspection of purchased assemblies and to detail inspection of metal parts and processes, and discussed the functions of the inspector engaged in the work and his relation to tool inspection. A consideration of assembly inspection included such items as the accuracy of completed assemblies, fuselage line-up and the installation of the various sub-assemblies. Mr. Feeley discussed final-assembly inspection under the divisions of the final line-up of the airplane, the testing of radio bonding, engine installation, inspection of the oil, gas and water systems, completeness of detail, and final engine test.

EXTERIOR OF THE PUBLIC AUDITORIUM
The American Society for Steel Treating Staged an Interesting and Valuable Attraction in This Building. Over 200 Exhibits of Machine-Tool Builders and Manufacturers of Equipment Were Shown

Relative to Mr. Feeley's remarks on the wood used in airplanes, Dr. St. John inquired how much loss must be allowed for material rejected on account of defects. Mr. Feeley replied that his company buys its airplane lumber with its own specifications, paying an extra price for it. The lumber received has probably not more than 10 per cent rejected from the raw material. As it proceeds through the factory, various defects are found, with consequent rejection of about 30 per cent. However, this amount does not represent a total loss, as much of this material can be used in making many small parts of the airplane. Dr. St. John discussed the advisability of X-raying the wood to anticipate the discovery of defects instead of waiting for them to be found as the lumber passes through the factory.

Paying inspectors on an incentive basis was a topic brought up by Chapin Hoskins, of *Factory*, for discussion. This system of payment has been used in other industries, but no one present at the session had heard of its being used in the automotive industry.



INTERIOR OF THE PUBLIC AUDITORIUM
This Shows a Portion of the Seventh National Steel and Machine-Tool Exposition. The Market Value of the Exhibits, Many of Which Were in Operation under Production Conditions, Was Said To Exceed $2,000,000

THE NATIONAL STEEL EXPOSITION

The Seventh National Steel Exposition of the American Society for Steel Treating presented an interesting and valuable attraction for the production men who spent considerable time at the Public Auditorium in examining the 200 or more exhibits that were shown by machine-tool builders and manufacturers of equipment. The market value of the exhibit was said to exceed $2,000,000. The attractiveness of this affair was greatly enhanced by the fact that many of the exhibits were in actual operation under production conditions. It was estimated that approximately 40,000 people visited the exposition during the week.

Great credit is due the American Society for Steel Treating for the successful accomplishment of this gigantic undertaking that proved to be of great educational value.

COOPERATION ENJOYED

Seldom if ever has the Society of Automotive Engineers enjoyed as generous cooperation as has existed with the American Society for Steel Treating with which the arrangements for the week's activities were made. The Steel Treaters held their Seventh Annual Convention and National Exposition of Machine Tools and Heat-Treating Equipment concurrently with the Production Meeting. Members of the American Society for Steel Treating were found at the Technical Sessions and Annual Dinner of the Society and the reverse was equally true.

Members of the Society were cordially invited to participate in the numerous entertainment features that were arranged by the American Society for Steel Treating, including golf, inspection visits, a smoker and frolic and the Grand Ball that was held at the Cleveland Hotel on the evening of Sept. 16. The ladies of the Society of Automotive Engineers were also royally entertained with the ladies of the American Society for Steel Treating.

OPEN HOUSE IN CLEVELAND

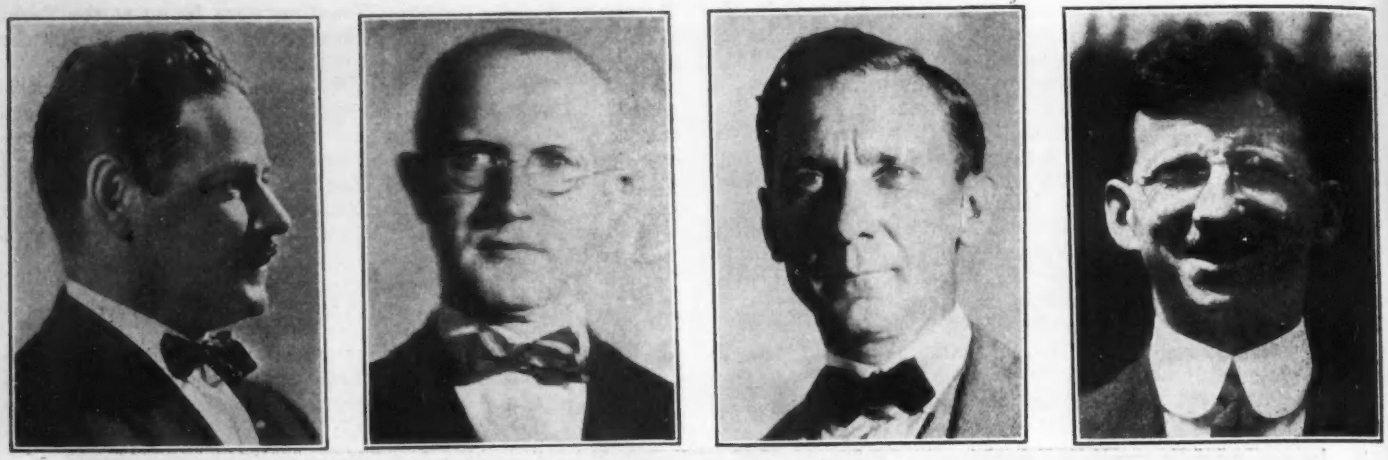
Cleveland factories very generously maintained open house for the inspection of their plants by members of the two societies who met simultaneously in the city. Among the visits that were made was one to the plant of the Ohio & Western Pennsylvania Dock Co., where the unloading of an ore boat was witnessed. Following this a visit was paid to the National Carbon Co., after which the plants of the White Motor Co. and the Cleveland Electric Illuminating Co. were inspected; following these visits the members proceeded to the General Electric Co.'s research laboratory at Nela Park where they enjoyed a very profitable afternoon. Other factory visits included the following plants: American Steel & Wire Co., Chandler Motor Car Co., Cleveland Automobile Co., Peerless Motor Car Co., Van Dorn & Dutton Co., Van Dorn Electric Tool Co., Warner & Swasey Co., and Brown Hoisting Machinery Co.

Members who visited these plants were shown every courtesy and appreciate very greatly the kindness of the factory executives in opening the plants for their inspection and also the assistance of the guides who so ably conducted these visits. A. H. Frauenthal was responsible for the satisfactory transportation of the members to these plants.

CREDIT TO WHOM CREDIT IS DUE

Success of Meeting the Result of Hard Work by Committee and Authors

Too great credit cannot be given to Chairman John Younger and the members of his Production Meeting Committee: Eugene Bouton, A. H. Frauenthal, K. L. Herrmann,



—A Collaborator with the Production Meeting Committee and Three of the Committee Members
From Left to Right They Are W. H. Eisenman, Secretary of the American Society for Steel Treating; L. L. Roberts, J. H. Teachout, and K. L. Herrmann

L. L. Roberts, and J. H. Teachout. Complete agreement was heard on all sides that the program was one of the most practical and valuable to production men that has ever been arranged by the Society.

The technical sessions were very efficiently conducted under the chairmanship of John H. Jaschka, John Younger, H. W. Alden, Eugene Bouton, and A. H. Frauenthal.

The preparation of a paper suitable for presentation at a national gathering of the Society is not an easy task. A great amount of time and effort is required. It is believed that the 1925 Production Meeting papers have set a new high standard of quality that will be hard to excel at future gatherings. The following contributed largely to the success of the meeting by cooperating as above indicated: G. F. Keyes, Mullins Body Corporation; Syd Smith, Studebaker Corporation of America; Mrs. Lillian M. Gilbreth, Gilbreth, Inc.; F. T. Jones, White Motor Co.; Louis Ruthenburg, Yellow Sleeve Valve Engine Works, Inc.; P. L. Tenney, Muncie products division, General Motors Corporation; Earle Buckingham, Niles-Bement-Pond Co.; R. M. Hidey, White Motor Co.; W. G. Careins, Ajax Motors Co.; R. M. Anderson, Holley Carbureter Co.; A. R. Kelso, Continental Motors Corporation; J. Gustaf Moohl, Cleveland Automobile Co.; R. F. Thalner, Buick Motor Co.; C. J. Ross, Buick Motor Co.; and J. J. Feeley, Glenn L. Martin Co.

In the absence of Syd Smith the paper on Sheet Steel Fabrication was presented in a very creditable manner by Rollin I. Mowry, of the Studebaker Corporation of America. Mr. Kelso's paper on the Analysis of Machine-Tool Maintenance was presented by John Younger, of *Automotive Abstracts* and Ohio State University. The paper on Inspection Methods prepared by C. J. Ross, of the Buick Motor Co., was well presented in the absence of Mr. Ross by R. B. Schenck, of that company.

A special word of appreciation is extended to K. T. Keller, vice-president and general manager, General Motors of Canada, Ltd.; to W. H. Eisenman, secretary of the American Society for Steel Treating; and to President Horning, members who were instrumental in making the Production Dinner a success. E. W. Austin, of the Timken Roller Bearing Co., deserves special mention for his arrangements for the Production Dinner.

The Society extends its thanks to the officers and members of the American Society for Steel Treating who contributed very largely in connection with the entertainment features in which many members of our Society participated.

AERONAUTIC MEETING PROGRAM

On the afternoon and evening of Wednesday, Oct. 7, the National Aeronautic Meeting of the Society will be held at the Hotel Astor, New York City. The afternoon session, commencing at 1:30, will be devoted to papers and discussion on Design and Construction; an Aeronautic Banquet will follow the afternoon session; and the evening session, commencing at 8:30, will cover Commercial Operation of Aircraft.

1:30 P. M.—Design and Construction Session

The Aeronautic Safety Code, Its Object and Meaning—Henry M. Crane, General Motors Corporation

The Evolution of the Racing Airplane—W. L. Gilmore, Curtiss Aeroplane & Motor Co.

Some Aspects of Aircraft Engine Development—George J. Mead, Pratt & Whitney Aircraft Co.

The Light Airplane and Low Powered Flying—W. Laurence Le Page, Gardner Publishing Co., formerly of Massachusetts Institute of Technology

6 P. M.—Aeronautic Banquet

Address by C. M. Keys, president, Curtiss Aeroplane & Motor Co.

Toastmaster, Henry M. Crane, past president of the Society

8:30 P. M.—Operation Session

Operation Facts from the Air Mail Service—J. E. Whitbeck, Air Mail Service

Operation Lessons from the Ford Air Lines—W. B. Stout, Stout Metal Airplane Co., Air Line Division, Ford Motor Co.

Reliability in Operation—J. Parker Van Zandt, Department of Commerce

The Aeronautic Meeting will be *open to all* persons seriously interested in the design, construction and operation of aircraft. Members of the Society are requested to spread the invitation to attend the technical sessions and the banquet in order that the value of the event may extend to the greatest number.

Tickets for the banquet at $4 each should be ordered at once from Society Headquarters, 29 West 39th Street, New York City.

NATIONAL MEETINGS CALENDAR

AERONAUTIC MEETING—New York City—Oct. 7

SERVICE ENGINEERING MEETING—Chicago—Nov. 9 and 10

AUTOMOTIVE TRANSPORTATION MEETING—Philadelphia—Nov. 13 and 14

ANNUAL DINNER—New York City—Jan. 14, 1926

ANNUAL MEETING—Detroit—Jan. 20, 21 and 22, 1926

AERONAUTIC MEETING ON OCT. 7

Sessions on Design and Construction and Operation with Banquet Intervening

With aviation now uppermost in the minds of many, the Society's National Aeronautic Meeting promises to attract widespread interest. The speakers who have agreed to present papers, as shown in the accompanying program, are men whose prominence in the field of aeronautics is well known; they will discuss topics of peculiar interest at this time and will base their addresses on a wealth of technical information that has come from long experience.

It is believed that the program of topics and speakers printed herewith speaks for itself. A more interesting array would be difficult to imagine.

Time and Place

The afternoon session of the Aeronautic Meeting will open promptly at 1:30. It will be followed by the Aeronautic Banquet that is scheduled to start promptly at 6 o'clock. The evening session will convene at 8:30. Both technical sessions and the Banquet will take place at the Hotel Astor, New York City.

The Pulitzer Race Meet will be held under the auspices of New York 1925 Air Races, Inc., at Mitchel Field, Long Island, beginning on Oct. 8, the day following the Aeronautic Meeting. It is believed that many of those who have planned to attend the races will come to New York City a day earlier in order that they may enjoy the program that has been arranged for the Society's Aeronautic Meeting.

Prominent Banquet Guests

C. M. Keys, president of the Curtiss Aeroplane & Motor Co., has consented to address the Aeronautic Banquet on a topic that will make a strong appeal to all engineers. The Society counts itself extremely fortunate in being able to enlist the cooperation of a man of such prominence with a well-established reputation as an eloquent speaker.

President Horning will be present to welcome the guests on behalf of the Society. Past-President Crane will act as toastmaster.

The Society will be honored by the presence of several distinguished representatives of the airplane industry abroad. Monsieur P. E. Flandin, president of the Aero Club de France, and Monsieur Louis Breguet, French airplane builder, have graciously accepted the Society's invitation to be present at the sessions and at the Banquet. Many other interesting and well-known figures in the aeronautic field, both in this Country and abroad, will enjoy the various events of the day.

Purchase Tickets Now

Orders for banquet tickets at $4 each should be sent to headquarters with remittance at once. Members cannot be assured of accommodations at the Banquet unless their reservations are made well in advance.

An Open Meeting

The National Aeronautic Meeting has been designed with special reference to the interests of Society members. It is the Society's wish, however, that non-members as well as members attend the meeting in large numbers. Every effort will be made to welcome all those who are seriously interested in the topics under discussion and to make the meetings most profitable to them in every respect.

TRANSPORTATION MEETING CHANGE

To Be Held at Benjamin Franklin Hotel, Philadelphia, Nov. 13 and 14

Chairman Herrington's Transportation Meeting Committee has decided to change the date of the Transportation Meeting to Nov. 13 and 14 in order that more satisfactory meeting arrangements may be available. The technical sessions and the Transportation Dinner will take place at the Benjamin Franklin Hotel.

Topics and Speakers

Three technical sessions will be devoted respectively to standardization, freight handling and store-door delivery, and motorcoach operation. Among those who have accepted the Committee's invitation to present papers are Robbins B. Stoeckel, commissioner of motor vehicles in the State of Connecticut; H. F. Fritch, Boston & Maine Railroad; Harland Horton, Philadelphia Rural Transit Co.; and W. F. Evans, Detroit Motorbus Co.

Parade of Transportation Equipment

Among the interesting events that will take place during the Transportation Meeting will be a street parade of transportation equipment. The Philadelphia members of the Transportation Meeting Committee and others from the Pennsylvania Section of the Society have been active for some weeks in making preparation for this event, that will be of outstanding interest.

The Transportation Dinner

On the evening of Nov. 13, the transportation engineers will enjoy a Transportation Dinner at the Benjamin Franklin Hotel. A. F. Masury has consented to act as toastmaster

SCHEDULE OF SECTIONS MEETINGS

OCTOBER

1—DETROIT SECTION—Testing Apparatus and the Methods Used in Conducting the Tests—O. T. Kreusser; visit to the proving grounds of the General Motors Corporation with inspection of the entire grounds and testing apparatus.
2—PENNSYLVANIA SECTION—Excursion to attend the seventh annual meeting of the Army Ordnance Association at Aberdeen, Md., Proving Ground.
8—INDIANA SECTION—Steam Cooling—A. Ludlow Clayden.
MILWAUKEE SECTION—Joint meeting with Chicago Section.
10—SOUTHERN CALIFORNIA SECTION—Exhibition flights at Clover Field; followed by papers by military and naval experts on various aeronautic subjects.
13—BUFFALO SECTION—Philosophy of Weight Reduction—L. H. Pomeroy.
14—DAYTON SECTION—The Use of Radio for Military Purposes—W. H. Murphy.
15—METROPOLITAN SECTION—Speeding Up Traffic Safely—John C. Long, Harold M. Lewis and Major Elihu Church.
19—CLEVELAND SECTION—The Small Car—O. E. Hunt.
23—WASHINGTON SECTION.

and arrangements have been practically completed to obtain a very prominent speaker who will appeal to all who attend.

PLANT INSPECTION

Through the courtesy of the Philadelphia Rural Transit Co., the members will be permitted to make a careful inspection of the equipment that is used in connection with the very extensive operation of this company.

Further information pertaining to the Transportation Meeting will be supplied in forthcoming issues of the *Meetings Bulletin* and in the November issue of THE JOURNAL. The meeting is to be open and it is hoped that it will attract a large number of Society members as well as those who are vitally interested as non-members in the Society's activities.

SERVICE ENGINEERING MEETING

Society to Cooperate with National Automobile Chamber of Commerce at Chicago

Judging from the interest that has been shown by Society members in meetings devoted to the subject of automobile maintenance, the engineers who are engaged in this line of endeavor find great value in the interchange of information derived from their experience. The Society will continue its activities in the service field and has arranged to cooperate with the National Automobile Chamber of Commerce in holding the Annual Service Engineering Meeting at the LaSalle Hotel, Chicago, on Nov. 9 and 10.

TOPICS AND SPEAKERS

The Society has arranged two of the sessions and the National Automobile Chamber of Commerce will be responsible for two others. The first session provided by the Society will deal with the topic of Corrosion in Internal-Combustion Engines. Frank Jardine of the Aluminum Co. of America, whose work along the lines of lubrication and corrosion is well known, will deliver a paper on this topic. A second paper will be presented by Sydney Bevin of the Tide Water Oil Co. These two papers will provide hitherto unpublished data concerning corrosion, a topic that is of vital interest to all service engineers.

Diagnosis of troubles and the choice of methods for remedying them will be discussed at the second S.A.E. session by C. L. Sheppy of the Pierce-Arrow Motor Car Co. and by Carl Breer and other representatives of the Maxwell-Chrysler Corporation. A number of other prominent members, including J. G. Vincent of the Packard Motor Car Co., have agreed to present discussion.

Additional details concerning the sessions of the Society and of the National Automobile Chamber of Commerce will be presented in a *Meetings Bulletin* and in the November issue of THE JOURNAL.

An interesting attraction that will take place in Chicago simultaneously with this meeting will be the Annual Meeting and Exposition of the Automotive Equipment Association.

INSPECT AIRCRAFT ENGINE LABORATORY

Pennsylvania Section's First Meeting of the Season Is Crammed with Interest

About 60 members of the Pennsylvania Section who attended the Section's first meeting of the season on Sept. 10 were treated to an inspection of the plant and facilities of the engine-testing laboratory of the Naval Aircraft Factory at the League Island Navy Yard and to a paper on the problems of testing methods presented by J. H. Geisse, senior engineer of the factory. Both the examination of the laboratory and the paper were crammed with so much material of interest that the members would gladly have spent a much longer time at the factory, according to Charles O. Guernsey, chairman of the Section.

The visitors were given a demonstration of the catapult launching of seaplanes which alone was well worth the trip. They were also shown tests of various starting devices, spark-plugs, magnetos, gasoline pumps, various indicators and other devices, and air-cooled aviation engines. Opportunity was afforded for an examination of the laboratory equipment, which is extremely well worked out and includes many details of interest that some of the members, at least, never had seen before. Among the unusual items of equipment were mercury scales for dynamometer stands, a peculiar design of wind tunnel for testing air-cooled engines, a special type of altitude testing device, and various minor details.

Mr. Geisse's paper was rather intimately related to the inspection trip and covered the various problems encountered in the working out of the testing methods. It also brought out some unusual facts relating to corrosion of piston-heads and to detonation, which is rather closely related to troubles that have been experienced with spark-plugs, pistons, valves and other parts.

The Section Chairman has announced the appointment of standing committee chairmen for the year as follows: Membership, E. A. Corbin; Publicity, F. L. Berger; and Papers and Arrangements, R. R. Whittingham.

Tentative plans for the October meeting are for a joint visit to the Aberdeen Proving Grounds with the Army Ordnance Association at the time of the National ordnance dem-

(*Concluded on p.* 384)

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

PROGRESS WITH ALUMINUM ALLOYS

Effect of Forging, Heat-Treating and Aging on Physical Characteristics

Aluminum alloys are being used to great advantage in the automotive industry. Parts that have to be light and at the same time are required to possess great structural rigidity as, for instance, crankcases and housings for transmissions and rear axles, are very successfully made of aluminum castings. The elements commonly combined with the aluminum, such as copper, zinc, and silicon, have a profound effect on the physical properties of the alloy. Pure aluminum is very ductile. Certain amounts of this ductility have to be sacrificed in the alloying with such elements as those mentioned above to obtain greater hardness and strength. Moreover, unless the alloying elements are most carefully selected and proportioned, casting defects are frequently encountered, such as cracks due to solidification shrinkage, hot-shortness, and porosity. Because of these defects, the tendency has been to put a large variety of slightly different alloys on the market. To meet the need for a small number of standard alloys, aluminum-alloy specifications that possess the best all-round physical characteristics are given in the S.A.E. HANDBOOK.

With the continued progress in aircraft and with the increasing need for reduction in the weight of motor vehicles, the need for stronger light metals is constantly increasing. For instance, it was realized that if wood and doped linen in airplanes could be replaced by metal that the fire hazard would be greatly decreased. In view of this demand a corresponding development in the art of forging aluminum alloys resulted.

About 15 years ago Alfred Wilm of Germany developed an alloy called duralumin. This became prominent when it was found that in the German airship L-72, which fell back of the French lines during the war, the structural framework was made entirely of duralumin. In the meantime, much progress has been made in this Country with similar alloys. These metals are now used extensively in the automotive industry for stampings, such as radiator casings, for connecting-rods, for wheel rims, and experimentally for wheels and frames. To produce the best physical properties it is necessary that the cast structure of the ingot be thoroughly modified by rolling, forging or other form of mechanical working. As the result of this mechanical working alone, the alloy possesses but moderate strength and very little ductility. If then heated to a suitable temperature, the metal can be annealed and in this condition is very ductile. If, however, the wrought alloy is heated and quenched at the proper temperatures, an appreciable increase in strength is noted. Further, on standing at either ordinary or slightly elevated temperatures, aging occurs. This brings about an increase in tensile-strength and hardness, with little or no change in elongation. The hardening effects in aging are caused by the precipitation of hard constituents in the form of very small particles. This aging proceeds rapidly at first, and after about 4 days the major portion of the effect has been realized.

Because of the great affinity of magnesium for oxygen, it has been found necessary in some applications to protect the metal with a bituminous varnish. Acids, with the exception of hydrochloric, have little effect on it. It has been found that soda and potash affect the metal strongly. Moreover, the metal should not be allowed to come into contact with steels or other metals containing copper, as otherwise corrosion will result if water is present. In construction, therefore, rivets of the same metal should be used.

TABLE 1—CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF AN ALUMINUM ALLOY

Chemical Composition

	Minimum	Maximum	Nominal
Copper, per cent	3.50	4.50	4.00
Magnesium, per cent	0.20	0.75	0.50
Manganese, per cent	0.40	1.00	0.50
Aluminum, per cent	92.00	...	Remainder

Physical Properties

	Hard-Rolled	Annealed	Heat-Treated and Quenched (Unaged)	Heat-Treated and Tempered (Aged)
Tensile-Strength, lb. per sq. in.	43,000	30,000	48,000	60,000
Yield-Point, lb. per sq. in.	30,000	9,000	.....	33,000
Elongation in 2 In., per cent	4	18	20	20
Brinell Hardness Number	80	54	78	95

The chemical composition and conservative physical properties of an alloy of the type under consideration are given in Table 1.

It will be noted that the characteristics given in the table meet most aeronautic specifications.

Another similar alloy, known as Alférium, has been developed in France by Schneider & Co. According to the information given by its sponsors, the physical characteristics of Alférium coincide closely with those of the metal of the type indicated above. An excellent example of use of Alférium is the monoplane, known as the Schneider SCH-10 Type M, which was designed and constructed for the French government by Schneider & Co. This plane is constructed entirely of Alférium. It is a military type, for bombing. On top of the wing is the fuselage containing the gunner's cockpits, one forward in the nose of the airplane and one aft of the pilot's compartment, which is in the center. Beside the pilot is a seat for the gunner, who controls the bomb releases.

The motive power is supplied by two Lorraine-Dietrich engines of 400 hp. each, located in nacelles on either side of the fuselage. The landing-gear is completely housed.

The general characteristics of this plane given by the constructors are approximately as given in Table 2.

The wing covering, as well as a number of other parts, are corrugated to secure greater rigidity. The corrugating is accomplished by a special press developed for the purpose of stamping the sheet without danger of cracking it. The material to be formed is put in a press that has a slotted

TABLE 2—CHARACTERISTICS OF THE SCHNEIDER SCH-10 TYPE M MONOPLANE

Wing-span, ft.—in.	60—8
Length, ft.—in.	38—5
Height, ft.—in.	10—10
Wing-Surface, sq. ft.	613.32
Weight, empty, lb.	5,830
Useful Load, lb.	2,200
Weight, Ready for Flight, lb.	8,030
Horizontal Speed at 16,400 ft., m.p.h.	136
Ceiling, ft.	22,960

U-section about 8 ft. in length. The edges of the U-section have been rounded slightly so that when formed, the section, instead of having a sharp bend, is slightly rounded.

Alférium takes a white silver polish that lasts almost indefinitely. It can be laminated, forged, stamped and drawn.

MOTOR-VEHICLE BRAKE SAFETY CODE

Committee Recommends Stopping-Distances in Tests of Braking Ability

At the 1924 National Conference on Street and Highway Safety, the Committee on the Motor Vehicle made in connection with the subject of Brakes and Braking, the recommendation that

> All motor vehicles, except possibly motorcycles and heavy trucks should be capable of stopping from a speed of 20 m.p.h. on a dry, smooth, hard-surfaced road, free from any loose material, by means of the service brake alone in a distance of not more than 50 ft. Emergency brakes should be capable of the same performance as service brakes, but as an absolute minimum requirement they should be capable of holding the vehicle on any grade which it can ascend.

It was stated then that the recommendation was made pending the adoption by constituted authorities of a code for standard braking-ability. Since then a technical sub-committee of the Sectional Committee on Safety Code for Brakes has been appointed. At a meeting of this Committee, the members expressed the opinion that the rate of deceleration should be the same for all classes of vehicle operating in the same stream of traffic. This Committee has carried out an analysis of required stopping-distances on over 330 trucks and motorbuses.

While other tests are still being carried on, particularly on heavy trucks, the following recommendations have been made to the Sectional Committee.

Recommendations for Passenger Vehicles Normally Carrying Seven Passengers or Less

Foot-Brakes.—On a dry, hard, level road free from loose material, the foot-brake shall be capable of stopping the car from a speed of 20 m.p.h. within a distance of 50 ft.

Hand-Brakes.—On a dry, hard, level road free from loose material, the hand-brake shall be capable of stopping the car from a speed of 20 m.p.h. within a distance of 75 ft.

Blanket Recommendations for All Vehicles Other Than Those Mentioned Above

On a dry, hard, level road, free from loose material, commercial freight-carrying vehicles, or passenger vehicles normally carrying more than seven passengers, or any such vehicles operating singly or in combination, except as hereinafter provided, shall be capable of stopping within a distance of 50 ft. from 20 m.p.h. upon application of both brakes simultaneously and within a distance of 75 ft. from 20 m.p.h. upon application of either brake alone. Provision shall be made for locking one brake in the position in which a stop is made.

Commercial freight-carrying vehicles weighing 4000 lb. gross, or under, operating singly, shall be capable of the same performance as that required for passenger vehicles carrying seven passengers or less.

On and after July 1, 1927, the requirements for all vehicles operated singly or in combination shall be the same as those now stipulated for passenger vehicles carrying seven passengers or less.

Note.—The requirement of having two independently operated sets of brakes is so general that it seems to call for no discussion. However, there are electrical brakes, about which doubt has arisen. The Committee is of the opinion that, in order to clarify a possible misunderstanding,

> An electrical brake, or other subsidiary brake, may be used instead of a mechanical foot-brake, if capable of the same performance as that required for foot-brakes, provided further, that there shall be no electrical or mechanical difficulties which would make such an electrical brake, or other device, inoperative before bringing the vehicle to a complete stop.

So far no recommendation has been made nor has any discussion been had on the method or means to be employed for determining the distances within which the vehicles are to be capable of stopping. At present various decelerometers are available. Moreover, two white lines are frequently used for determining the ability to decelerate. Those who desire to do so are invited to make suggestions. Any member wishing information of a technical nature will please communicate either with the Research Department of the Society or directly with H. H. Allen at the Bureau of Standards, City of Washington.

In connection with the work done by the above-named technical committee, it will be of interest that the Department of Public Works of Massachusetts not only has carried on extensive tests to determine the brake effectiveness that should be required of motor vehicles, but has also investigated the average condition of braking equipment in use.

In a letter of Sept. 9, Frank A. Goodwin, registrar of Motor Vehicles of Massachusetts, writes in part.

> It was found that vehicles equipped with two-wheel brakes in perfect condition could be stopped in from 30 to 35 ft. from a speed of 20 m.p.h., and the Registrar has ruled that the foot or service brake must stop the vehicle in 45 ft. or less from a speed of 20 m.p.h. if the vehicle is to be stopped within a proper distance as required by law. The emergency or hand-brake is generally less efficient than the foot brake but should be so constructed as to stop the vehicle within the same distance,—namely, 45 ft. The law makes no distinction between the effectiveness of the two brakes.
>
> In our enforcement of this law we found that 75 per cent of the trucks in use had defective brakes and many of them could not be repaired so as to stop the vehicle within the required distance. The Registrar subsequently ruled that until such time as the manufacturers of trucks had had an opportunity of correcting defects in braking equipment certain leeway was to be given in the case of governed vehicles as follows:

Governed Speed, M.P.H.	Decelerometer Reading, Ft.	Calculated Deceleration, Ft. per Sec. per Sec.
18	60	7.2
15	80	5.4
12	100	7.3

The decelerometer readings given above are taken from an instrument that is set to give for the prevailing deceleration the distance required to stop the vehicle if the brakes are applied at a speed of 20 m.p.h., hence the third column has been added by the Research Department.

Inasmuch as individual States are likely to establish various and perhaps conflicting regulations, the need for establishing basic figures by a technical committee will be seen and comments on the present status of the work as well as cooperation is invited.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

VEHICLE LIGHTING LAWS COMPILED

Requirements of State Regulations Outlined by the National Lamp Works

Information recently compiled by the National Lamp Works of the General Electric Co. will be of considerable value to car builders interested in the requirements of various States with regard to motor-vehicle lighting. The more important requirements covered are abstracted hereinafter, but engineers desiring copies of the complete tabulation which includes all requirements relating to motor-vehicle lighting can obtain copies from the National Lamp Works, Cleveland.

Head-Lights.—Nineteen States have issued lists of approved head-lamp glasses. These are California, Connecticut, Delaware, District of Columbia, Iowa, Maine, Maryland, Massachusetts, Missouri, Nebraska, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Texas, Virginia, and Vermont.

Eleven States have adopted the 1920 Illuminating Engineering Society Specifications or the American Standard for Head-Lamp Illumination adopted in 1922. These States are California, Connecticut, Maryland, Massachusetts, Nebraska, New York, Ohio, Oregon, Pennsylvania, Texas, and Wisconsin.

Although it is generally recognized that dimming is undesirable, it is required by the following 13 States: Colorado, Florida, Illinois, Indiana, Kansas, Michigan, Montana, New Hampshire, Ohio, Oregon, South Carolina, South Dakota and Vermont.

Tail-Lamps.—Although red is considered to be the universal color for tail-lamps, either red or yellow is permissible in Texas and either red or green in Wyoming. No color is specified in Florida.

The majority of the States specify the distance that the license-plate numerals illuminated by the tail-lamp shall be visible from the rear. The average distance is 50 ft., but 100 ft. is specified by Idaho, Montana and Utah.

Massachusetts is the only State that issues a list of approved devices for tail-lamps; and it requires that they meet the Illuminating Engineering Society Specifications for Tail-Lamp Illumination.

Stop-Signals.—Several States require the installation of stop-signals on vehicles from which hand-signals from the driver's seat are not visible from the rear. These States are Arizona; California; Indiana, on motorcoaches only; Missouri; Oregon; Utah; and Washington. The States of California, Connecticut, Idaho, Oregon, and Washington issue lists of approved stop-signals.

PISTON AND PISTON-RING OVERSIZES

Three More Specified to Have S. A. E. Standard Meet All Engine Requirements

To obtain uniform practice as to the amount of metal removed in regrinding worn cylinders, the Society adopted in 1912 cylinder oversizes of 0.01, 0.02, 0.03 and 0.04 in. Owing to changes in the practice of refinishing cylinders, piston and piston-ring manufacturers have found it more and more difficult to meet the increasing orders for non-standard oversize pistons and piston-rings.

After general discussion of this situation, the Division of Simplified Practice of the Department of Commerce called a conference in December, 1924, of piston, piston-ring, and passenger-car manufacturers. This Conference was attended by several representatives of piston-ring manufacturers, as well as by representatives of the Society of Automotive Engineers, the National Automobile Chamber of Commerce, the General Motors Corporation and the International Motor Co. In the discussion it was brought out that certain piston-ring manufacturers find it necessary to hold 4800 sizes in stock to meet current requirements. Although it was recognized that the piston-ring manufacturers were, in a certain measure, responsible for this uneconomical situation, it was appreciated that the recognition of standard oversizes by both automobile and piston-ring manufacturers would greatly improve conditions. It was voted to refer the problem to the Society with a request that the present piston-ring oversize standard be revised to specify a series of oversizes that would meet all requirements for internal-combustion engines.

As a result, a Subdivision of the Engine Division was appointed with A. W. Reader, of the General Motors Corporation, as chairman; the other members being R. J. Broege, of the Buda Co.; and A. F. Milbrath, of the Wisconsin Motor Mfg. Co. In order that the Subdivision recommendation might be based on the best engineering information, the practices of 30 representative builders of passenger-car, 6 of tractor, 7 of motorboat and 15 of truck and industrial engines were reviewed. The following recommendation was based on an analysis of the practice of these companies:

> Standard oversize pistons for passenger-car, marine and airplane internal-combustion engines shall be 0.003, 0.005, 0.010, 0.015 and 0.030 in. The standard oversizes for tractor, truck and industrial internal-combustion engines shall be 0.010, 0.020, 0.030 and 0.040. Larger oversizes, when necessary, shall be held to multiples of 0.010 in.
>
> Piston-rings shall be held to the same oversizes, omitting the 0.003-in. oversize, as are specified for pistons.

This recommendation, which will constitute a revision of the present S.A.E Standard if adopted, will be acted upon at the next meeting of the Engine Division. The opinion of the industry as to whether these oversizes will meet all requirements is being determined by a general letter that has been sent to the manufacturers of passenger-cars and engines.

USE OF "PHAETON" INCREASING

"Brougham" Used to Indicate Both Two-Door and Four-Door Five-Passenger Bodies

The resurvey of the names used for the various types of open and closed bodies has been made by the Society so that the Passenger-Car Body Division might consider at this time if any necessity for changing the standard nomenclature exists. The resurvey, which is given in Tables 1 and 2, covering owner-driven and chauffeur-driven types of car body indicates a definite trend toward the use of "phaeton," which was recommended in place of "touring car" by the Division in 1922.

The reason for recommending the use of the term "phaeton" instead of the term "touring car" is that the latter has lost its significance as applying to any particular type of body, as all types of body are used for touring. The term "phaeton" has long been used extensively in Europe and to a considerable extent in America in connection with

TABLE 1—NAMES USED FOR OWNER-DRIVEN TYPES OF BODY[1]

Name of Car			Five or Seven-Passenger Open Cars		Five-Passenger Closed Cars					
					Two-Door			Four-Door Close-Coupled		
	Roadster	Coupe	Phaeton	Touring Car	Coach	Brougham	Special Names	Brougham	Special Names	Sedan
Ajax				x						x
Apperson	(a)	x	x					x		x
Auburn	x			x				x		x
Buick	x	x		x			(j)		(o)	x
Cadillac	x	x	x (4)	x (7)		x	(k)			x
Case	x	x		x				x		x
Chandler	x			x	x					x
Chevrolet	x	x		x	x					x
Chrysler	x	x	x		x	x				x
Cleveland		x		x	x					x
Cunningham	x	x		x						x
Davis	x		x							x
Diana	x	(f)	x		x	x				x
Dodge	x	x		x	x					x
Duesenberg	x	x	x							x
DuPont	x			x						x
Durant	x	x		x	x					x
Elcar	x	x	x		x			x		x
Essex				x	x					
Flint	x	x	x (5)	x (7)		x		x		x
Ford	x	x		x			(l)			x
Franklin	(b)	x		x					(p)	x
Gardner	x	(f)		x		x				x
Gray		x		x						x
Hudson				x	x			x		x
Hupp	x	x		x					(q)	x
Jewett	x			x	x					x
Jordan	x	(g)		x				x		x
Junior 8	x			x				x		x
Kissel	(c)	x	x			x		x		x
Lexington	x			x						x
Lincoln	x	x	x (5)	x (7)						x
Locomobile	x			x						x
McFarlan	x	x		x						x
Moon	x	(f)	x		x	x				x
Nash	x	(h)		x						x
Marmon	x	x	x (5)	x (7)				x		x
Oakland		x		x	x				(r)	x
Olds				x	x					x
Overland		x		x			(j)			x
Packard	x	x		x					(q)	x
Paige			x							x
Peerless	x	x	x				(m)	x	(s)	x
Pierce-Arrow	(d)	x		x	x		(n)			x
Reo	x	x		x						x
Rickenbacker	(e)	x	x						(t)	x
Rollin		x		x		x				x
Rolls-Royce	x		x (5)	x (7)						(u)
Star	x	(i)		x			(j)			x
Stearns		x		x			(m)			x
Studebaker	x	(g)	x		x			x		x
Stutz	x	x	x (5)	x (7)				x		x
Velie	x	x	x						(f)	x
Wills	x	x	x					x		x
Willys Knight	x	x		x					(n)	x
Totals	40	36	20	41	16	8	8	14	9	53

[1] Figures in parentheses are number of passengers; letters refer to the special names listed below.
(a)—Coupe-Roadster with non-collapsible top.
(b)—Sport-Runabout.
(c)—Speedster.
(d)—Runabout.
(e)—Uses name Roadster; Coupe Roadster is used for model with non-collapsible top.
(f)—Cabriolet-Roadster.
(g)—Uses name Coupe and Victoria.
(h)—Victoria.
(i)—Coupster.
(j)—Two-Door Sedan.
(k)—Chummy-Sedan.
(l)—Tudor Sedan.
(m)—Coupe.
(n)—Coupe-Sedan.
(o)—Brougham-Sedan.
(p)—Sport-Sedan.
(q)—Club-Sedan
(r)—Landau-Sedan.
(s)—Four-Door Sedan.
(t)—Coach.
(u)—Enclosed-Drive Cabriolet.

passenger cars and is the name of a horse-drawn prototype. Several American car-builders use both terms—"phaeton" for the five-passenger and "touring car" for the seven-passenger open car. But, out of the 61 times either of these names was used, "phaeton" was used 20 times, or practically 33 per cent.

The Passenger-Car Body Division has not recommended a standard name for the five-passenger two-door closed type of body. This action was based on the impression that this type could be described properly by use of the existing nomenclature, and that the inconvenience of the seating arrangement would cause a trend in favor of a three or four-door body. The resurvey indicates that, of the 31 companies making this type of body, only slightly over one-half use the term "coach."

Of the 23 companies making a three or four-door close-coupled closed body, the large majority use the term "brougham." The principal objection to the "misuse" of this word, which of course has in the past been recognized as the proper name for a body of the same general description as the limousine except that the non-collapsible roof does not extend over the driver's compartment, is the fact that, while many companies are using the name for the four-door type of body, others are using it for the two-door type. Prospective purchasers are therefore unable to tell what type of body is meant in advertising or catalogs when the term "brougham" is used unless a photograph is shown or the seating arrangement indicated. The fact that the term

TABLE 2—CHAUFFEUR-DRIVEN TYPES OF BODY[2]

Name of Car	Berline	Limousine	Brougham	Landaulet	Coupe-Landaulet	Sedan-Landaulet	Berline-Landaulet	Limousine-Landaulet	Brougham-Landaulet	Cabriolet
Buick	(aa)	x								
Cadillac	(ab)	x	(af)							
Chrysler			(af)							
Cunningham	(ac)		(af)							x
Davis	x									
Duesenberg	x		x							
Franklin	(ac)									x
Kissel	x	x		x			x			
Lincoln	(ad)		(af)							
Locomobile	(ac)	x	x							x
Marmon	(ae)									
Packard	(ae)	x	x	x	x	x	x	x	x	x
Paige		x								
Peerless	x	x								
Pierce-Arrow	(ac)	x	(ag)	(ah)		(ai)	aj)	(ak)		
Rolls-Royce	(ad)	x	x						(al)	(am)
Studebaker	x									
Stutz	x									
Wills	(ac)	x	(af)							

[2] Letters indicate special names used and listed below.
(aa)—Limousine-Sedan.
(ab)—Imperial-Surburban.
(ac)—Enclosed-Drive Limousine.
(ad)—Suburban Limousine.
(ae)—Sedan-Limousine.
(af)—Town-Car.
(ag)—French Limousine.
(ah)—Landau.
(ai)—Sedan-Landau.
(aj)—Enclosed-Drive Landau.
(ak)—Limousine-Landau.
(al)—Cabriolet.
(am)—Salamanca.

"brougham" has been taken from the recognized nomenclature for chauffeur-driven types of body is offset by the fact that car builders are now using the term "town car" in place of "brougham" for this type of body. If this becomes general practice, the latter term is available for its present popular application.

The opinion and comments of Society members with reference to the desirability of recognizing "coach" and "brougham" in view of present usage will be appreciated by members of the Passenger-Car Body Division, who will consider the matter at a meeting early this Fall.

NATIONAL DIRECTORY OF SPECIFICATIONS

Volume Containing Information about 6000 Generally Used Commodities Issued

The Society has been informed by the Bureau of Standards at Washington, that the National Directory of Commodity Specifications, which is being issued by the Bureau is now ready for distribution. The volume contains information regarding specifications that are in general use for more than 6000 commodities, by whom they were prepared and where copies can be obtained. In it are conveniently indexed for ready finding about 27,000 specifications prepared by the Federal Specifications Board, the various departments of the Federal Government, State and city purchasing agents, public utilities, technical societies, and trade associations. The accompanying table indicates the wide range of commodities covered.

SUMMARY OF COMMODITIES AND SPECIFICATIONS

Decimal Class	Commodity Groups	Commodities Indexed	Approximate Number of Specifications
000	Animal and Animal Products.	350	1,600
100	Vegetable Food Products, Oil Seeds, Expressed Oil and Beverages	525	2,100
200	Other Vegetable Products (except Fibers and Wood)	400	800
300	Textiles	275	1,900
400	Wood and Paper	625	3,300
500	Non-Metallic Minerals	725	3,300
600	Ores, Metals and Manufactures (except Machinery and Vehicles)	1,700	6,400
700	Machinery and Vehicles	800	2,900
800	Chemicals and Allied Products	600	2,400
900	Miscellaneous	650	2,400
	Total	6,650	27,100

The Advisory Board that was organized in connection with the preparation and publication of the Directory, comprised representatives of the American Electric Railway Association; American Engineering Standards Committee; American Hospital Association; the American Hotel Association; American Society for Testing Materials; Associated Business Papers, Inc.; Associates for Government Service, Inc.; Chamber of Commerce of the United States; National Association of Manufacturers; National Association of Purchasing Agents; National Conference of Business Paper Editors; National Conference of Governmental Purchasing Agents; National Electric Light Association, and the Society of Automotive Engineers, Inc.

Copies of the book, which is bound in cloth and contains 385 pp., can be obtained from the Superintendent of Documents, Government Printing Office, City of Washington. The price is $1.25 per copy.

STANDARDS COMMITTEE ACTIVITY

Since January, 1923, a monthly bulletin has been issued to the members of the Standards Committee, the Council and other interested members covering the Standards Committee activity. An important part of this bulletin is a summary of the number of subjects on which actual progress has been made, the number of subjects renewed or assigned by the Council, the number discontinued, the total number under consideration, the number of actual recommendations adopted, and the number of Division and Subdivision meetings. A recapitulation of these items giving the 1923 and 1924 monthly averages, the 1925 monthly average to date and the activity for the month of August is given in the accompanying table.

SUMMARY OF STANDARDS COMMITTEE DIVISION ACTIVITY

Month or Monthly Average	August, 1925	1925	1924	1923
Subjects Active during Month	16	21	20	21
Subjects Assigned or Renewed	2.0	8.0	5.6	4.8
Subjects Discontinued	1.0	5.0	2.7	3.8
Subjects in Progress	55	56	73	83
Recommendations Submitted	0.0	3.6	4.1	4.6
Meetings	0.0	2.5	2.8	4.1

AERONAUTIC SAFETY CODE PUBLISHED

The first major step in the work of the Aeronautic Safety Code Sectional Committee, which is sponsored by the Bureau of Standards and the Society, is now completed with the publication of the Code. The work on the Code has been in progress since 1920 by a carefully selected and widely representative group of experts in the aeronautic and closely related fields. The several parts of the Code were printed in tentative form and widely distributed for the purpose of securing constructive criticisms and suggestions that were subsequently given the broadest possible consideration in preparing the final Code. The scope of the Code was outlined in the June, 1925, issue of THE JOURNAL, on p. 581.

The Code is issued as a Tentative American Standard under the procedure of the American Engineering Standards Committee, it having been approved by the Bureau of Standards early this summer and by the Society at its Semi-Annual Meeting at White Sulphur Springs, W. Va., last June. The Code is printed in pamphlet form and can be obtained from the Society at $1.50 per copy in small quantities.

COOPERATION IN STANDARDIZATION

R. M. Hudson Reviews Work of Division of Simplified Practice in Automotive Field

It has always been recognized that the Society's principal role in automotive standardization is to formulate standards rather than to reduce them to actual practice. This policy has been followed on the basis that if standards were worthwhile, they would be adopted generally by the industry. The wisdom of this policy is indicated by the extent to which the majority of S.A.E. Standards have been adopted generally.

Owing to the increase in the scope of the Society's activities and the large number of standard specifications printed in the S.A.E HANDBOOK and under Division consideration, many important specifications are now overlooked when new designs are laid down. It is this situation that has warranted the Division of Simplified Practice of the Department of Commerce in considering recently certain automotive subjects.

The Division of Simplified Practice was organized by Secretary Hoover in 1920. Although its primary purpose is to bring about simplification in common commercial commodities, such as paving brick, lumber, milk bottles and sheet steel, it is considered that many parts used by the automotive industry can be simplified without involving engineering considerations.

The following statement by R. M. Hudson, chief of the Division of Simplified Practice, which outlines the policy of the Division and the "Conference" method of furthering the adoption of automotive standards, should prove of interest to Society members who are desirous of more general adoption of S.A.E. Standards.

Competition has tempted many a manufacturer to

make his products in an infinite variety of sizes, models, patterns, types, and styles. Eventually, the manufacturer seeks relief from excessive inventories, idle stocks, and idle capital caused by over-diversification, and turns to standardization.

The automotive industry stands pre-eminent as a firm believer in the advantages and value of standardization and owes much of its success to its faith in this principle.

There is, however, in this industry, as well as in all other fields where standardization efforts are carried on, an ever-present problem—that of getting the results of those efforts applied in actual practice. It is one thing to have standards appear in a handbook, and quite another thing to have them appear in the finished product. It is only when the "paper" standards are transmuted into the metal of the car itself that their real values are adequately demonstrated. The production of standards is only a beginning. Getting them accepted is another important step. But getting them applied in practice is the biggest job of all.

It is the writer's observation, based on 4 years of intensive effort in the promotion of standards over a wide range of industries, that "standards, to be used, must be sold." "Sold," not only to the group that is to use them, but also to the group that designed them, so that the latter will have that faith in their own effort which will cause them to work persistently for the application of the standards they have produced.

This is why, in the case of each "Simplified Practice Recommendation" emanating from the Department of Commerce, the committee that developed the standards for the industry concerned therewith is charged with the responsibility of staying with its job until the recommendation is actually accepted and applied by the members of that industry, as well as the distributing and consuming groups on whom the industry depends for its market. To date, 43 recommendations have been accepted by over 1200 trade associations, and frequent joint audits made by the Standing Committees and the Division of Simplified Practice show that the degree of adherence to the recommendations runs as high in some cases as 95 per cent.

Recognizing that the S.A.E. "standards-making" procedure does not provide for the same intensive follow-up in behalf of its products as does the procedure of our Division, the Division's assistance has been offered in securing from manufacturers, distributors and consumers of automotive parts a more general acceptance of S.A.E. Standards, and, consequently, a more widespread application of those standards in actual practice.

Though an actual test of the practical value to the Society of such cooperative assistance has not yet been made, a program is under way which should result in a number of "test-cases." These include spark-plugs, brake-lining, taper roller-bearings and oversize piston-rings. In each of these instances, the Division of Simplified Practice had previously been requested by members of the industries themselves to assist in reducing the present variety in sizes and dimensions. Representatives of manufacturers, distributors and purchasers of each of these commodities, as well as members of the Society, were invited to attend the Conferences on these projects held at the Division's headquarters in the City of Washington. As a result of these Conferences the Society was asked to review the respective specifications in the light of the viewpoints expressed.

It is planned to re-convene the original Conferences when the revised standards are ready for presentation by the Society to the Division of Simplified Practice. From then on, the Division of Simplified Practice will apply the same procedure to securing acceptance of the standards that it has used so successfully in the 43 cases previously cited.

The Division of Simplified Practice is confident the results will be as gratifying in the automotive field as they have been in others, and looks forward to the outcome of this program as another demonstration of the value of cooperation in standardization.

TO CONSIDER MOTORCOACH BATTERIES

Suggestions have been recevied from various sources that the S.A.E Storage-Battery Division undertake to establish the maximum over-all dimensions for motorcoach batteries, along lines similar to those that were followed in establishing standard battery sizes for passenger cars and motor trucks.

At the request of the Chairman of the Storage-Battery Division, the Society has therefore undertaken to compile a list of battery sizes and capacities used by the motorcoach builders. A general letter has been sent to the motorcoach and storage-battery manufacturers in order that the final list may represent current practice.

SUPPLEMENT TO BOOK OF STANDARDS

The first supplement to the 1924 issue of the American Society for Testing Materials triennial book of standards is now being mailed to the members. The supplement contains the 36 new and revised standards adopted in 1925.

FLARED-TYPE TUBE-FITTINGS APPROVED

The Marine Committee of the National Fire Protection Association has specified in its regulations for internal-combustion engines for motorboats adopted at the annual meeting in May, 1925, that pipe connections shall be "of the solderless type and in accordance with the Society of Automotive Engineers Standard Practice Code published in the S.A.E. Handbook."

EDWARD Y. DAVIDSON, Jr.

FOLLOWING an illness of but a few days, Edward Y. Davidson, Jr., illuminating engineer for the Macbeth-Evans Glass Co., Charleroi, Pa., died at Chicago, on Aug. 16, 1925, aged 27 years. He was born at the City of Washington on Dec. 30, 1897. Following his preliminary education, he attended the Carnegie Institute of Technology from 1915 to 1919 and was graduated in 1919 from that institution of learning, receiving the degree of bachelor of science in electrical engineering.

His connection with the Macbeth-Evans Co. was formed on Jan. 1, 1920, and his subsequent activities related to design, installation and sales for that company. His capabilities and promise as a writer are indicated by his article on Home Lighting, printed in the *Ladies Home Journal* for October, 1920, and by his treatise on Motor Lenses and Reflectors, Their Functions and Uses, published in 1921.

Mr. Davidson was an associate member of the Illuminating Engineering Society and was elected to Associate Member grade in the Society of Automotive Engineers on Jan. 10, 1921.

Applying Jigs and Fixtures to Engine-Block Machining

By J. G. Moohl [1]

Production Meeting Paper *Illustrated with* Photographs

ABSTRACT

STATING first the several important factors affecting jig-and-fixture design, the author emphasizes the necessity for cooperation between the engineering and the tool-engineering department and says that, in the plant specified, the tool engineer determines the position of locating points for machining operations on the engine block. Details of the first machining operation are given and the methods of loading and clamping the work are outlined.

By adhering to accepted principles of design, and by utilizing all other means of cost-reduction, equipment of the plant with adequate jigs and fixtures is accomplished at minimum expense. Use of duplicate clamping parts on as many jigs as possible saves time and reduces the stock of replacement parts needed. Strength and rigidity of fixtures are essential. Heavy base-sections are necessary, bushing plates should have a section deep enough to prevent warping and ample chip-clearance should be provided between the fixture and the work. All locating surfaces should be self-cleaning. In conclusion, a specific example is given of the advantage gained by complete cooperation among the engineers and the departments concerned.

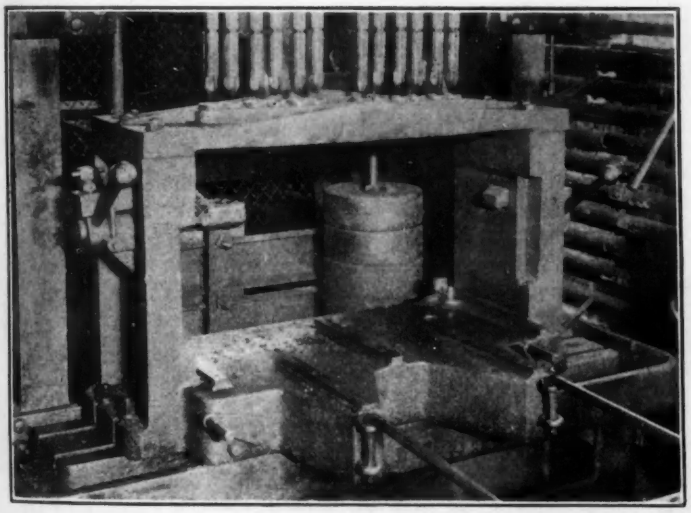


Fig. 1—Fixture for Core-Drilling Valve-Seat Holes
In General, a Number of Operations on the Same Piece Can Be Performed with Jigs Having Bodies Cast from the Same Pattern

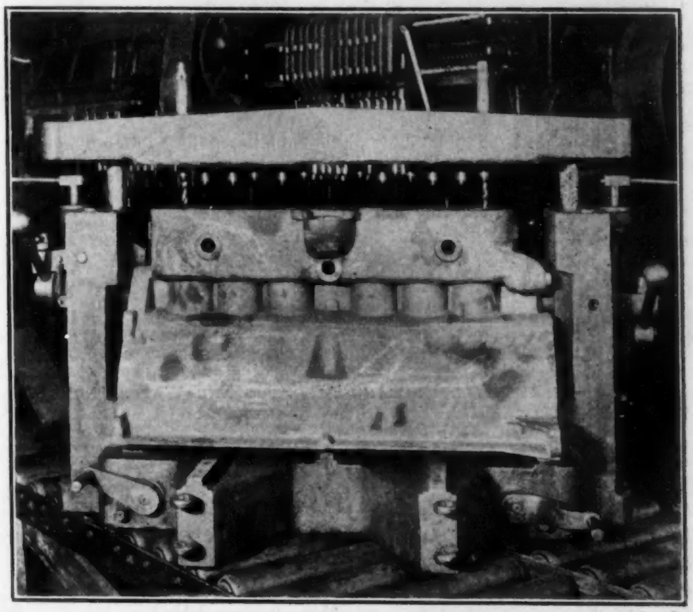


Fig. 2—Fixture for Drilling Valve-Guide Holes
Shown with the Block Casting in Place. This Fixture Has a Movable Drill-Plate with Bushings Extending into the Valve-Seat Holes. The Plate Is Attached to the Rail of the Machine and Moves Up and Down with the Spindles. The Two Long Guide-Posts Hold It in Alignment when the Plate Is Raised. The Bushings Are Outside of the Valve Holes when the Plate Is in the Raised Position and the Casting Can Be Slid into Place. When the Plate Is Down, the Bushings Are Close to the Work

IN designing jigs and fixtures for large or for medium production the tool engineer must consider several factors, among the most important being accurate location of the work; firm but rapid clamping-facilities and loading-means; reduction of expense by utilizing similarity of patterns, bushings and other parts; and the general design of the fixtures themselves. This paper will attempt to describe very briefly how these points are carried out in machining engine-blocks at the plant

[1] Tool supervisor, Cleveland Automobile Co., Cleveland.

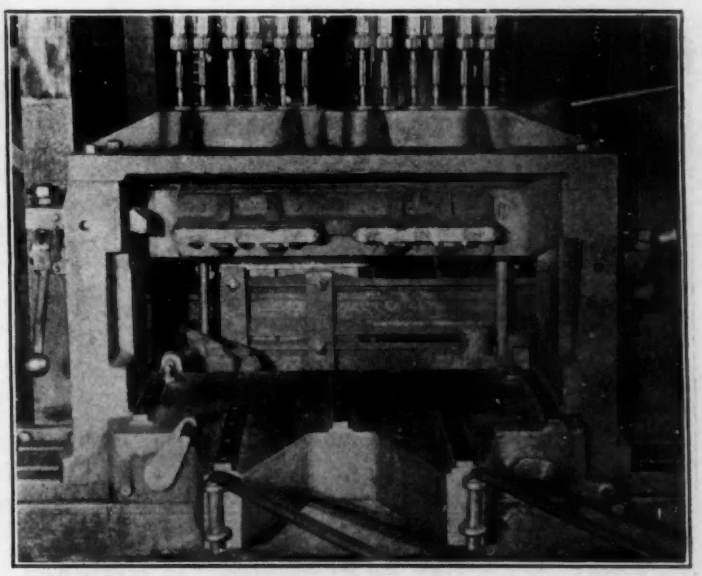


Fig. 3—Line Reaming Fixture for Valve-Seat and Valve-Guide Holes
Notice the Lower Row of Bushings To Take the Reamer Pilots

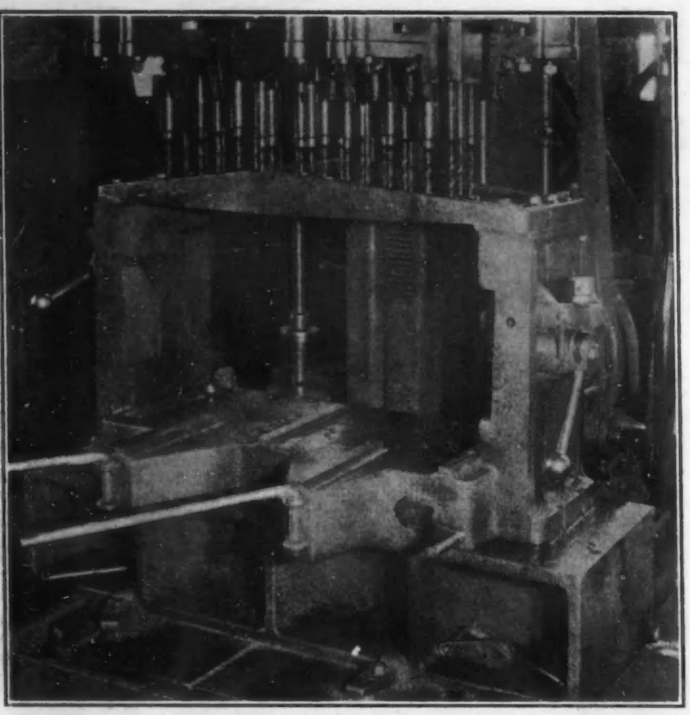


FIG. 4—FIXTURE FOR DRILLING ALL STUD AND WATER HOLES
These Holes Are in the Top of the Castings and Are Drilled on a Multiple-Spindle Machine

of the Cleveland Automobile Co. This organization considers that cooperation between the engineering and the tool-engineering department is of utmost importance and, in line with that idea, it was decided that the tool engineer should determine the position of locating points for machining operations on the engine block.

The first operation consists of milling the top, side and bottom on an Ingersoll milling machine, for which the location of the work in the fixture must be made from cast surfaces. These surfaces are checked to a target fixture. In the second operation, two ¾-in. locating-holes in one side of the bottom flange are drilled with a combination drill and reamer. These two reamed holes are then used for locating purposes in every subsequent operation, and the accumulation of error is thus prevented. To assure long life and successful operation of the jigs, these holes must be large enough so that the locating pins and dowels can be of ample size to withstand wear and strains. Disappearing dowels are used throughout, so that loading can be accomplished by sliding the heavy casting in on hardened strips without lifting it over any protruding dowels or pins. The disappearing dowels, operated by a rack and pinion arrangement, work in standard interchangeable slip-bushings of a type that is used in every possible application throughout the shop, more than 1000 having already been put into use.

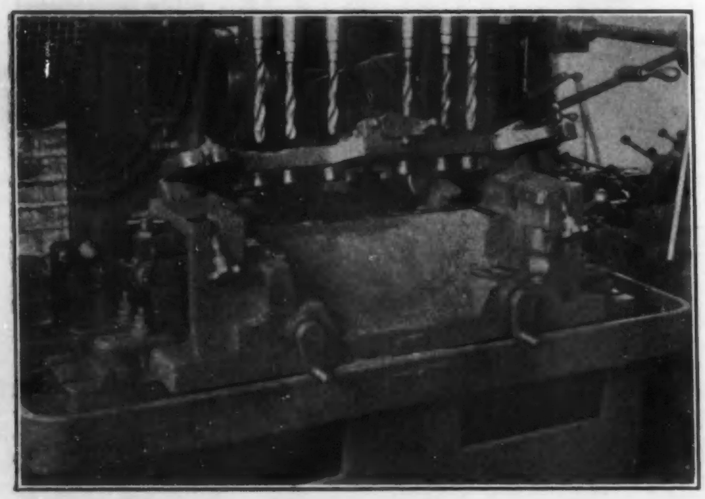


FIG. 5—CYLINDER-HEAD FIXTURE FOR DRILLING SPARK-PLUG HOLES
Notice the Permanent Stops and the Equalizing-Cam Arrangement in the Bushing Lid for Locating the Work from the Combustion-Chamber. The Hole on Each End Is Drilled with the Combination Drill and Reamer and Used for Locating Purposes in all Other Operations. Notice Also How the Surfaces Are Sloped Away from the Locating Point To Prevent the Accumulation of Chips

LOADING AND CLAMPING

In determining the means of loading and clamping the work, the designer has a large variety of methods at his disposal and, to assure the best possible design, he should consider a number of ways of accomplishing the same result and select the one most suitable for speed, safety, economy and durability.

A jig that is not quick-acting usually will prove to be a costly piece of equipment. The average reloading time for all jigs in the engine-block department at the plant already mentioned is 12 sec. For heavy work, such as engine castings, if all obstructions that the piece would need to be lifted over are eliminated and stops are used to locate it approximately, the loading time will be reduced greatly. Clamps operated by cams are in most cases quickest and most satisfactory, except for milling operations, where something more solid must be used.

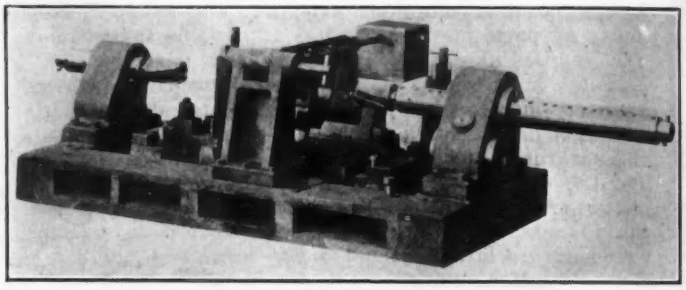


FIG. 6—ROUGH-BORING FIXTURE FOR CRANKSHAFT AND FOR CAMSHAFT HOLES
The Two Crank Boring Bars, with Core Drills Attached, Are Shown in Place

To equip the plant with jigs, tools and the like for a limited expenditure of money, the tool engineer must resort to every available cost-reducing means. Much can be done directly on the drawing board and, by adhering to certain principles of design, the cost can be reduced considerably without detracting from the usefulness of the tool. In general, a number of operations on the same piece can be performed with jigs having bodies cast from the same pattern, as in Figs. 1 to 4. Since patterns represent a large part of the cost of a jig, much expense can be saved in this way. Frequently an entire series of jigs can be designed so that, by changing a boss here and there or perhaps adding a loose piece or two, one pattern serves for the jig bodies of all. Six jig-bodies used in machining Cleveland six-cylinder engine-blocks were cast from the same pattern and, all along the line, the different jigs have been kept as closely alike in design as possible, the only substantial difference in many cases being in the bushing plates.

Appreciable expense is also saved by using in every possible case a single type of standard removable-liner

(*Concluded on p.* 338)

The Problem of Gear Production

By EARLE BUCKINGHAM[1]

PRODUCTION MEETING PAPER

ABSTRACT

STATING that the production of gears presents problems more baffling than those of other lines of production, the author believes the first essential for satisfactory results to be suitable means for detecting and measuring errors. The main difficulty here lies in devising means of measurement that are at once simple, rapid and effective, rather than to rely upon delicate laboratory-instruments unsuited for usage in production work.

Very slight errors in gears cause serious troubles and, since gears must be hardened, their production demands a high degree of precision under the most unfavorable conditions. Forming and generating constitute the two general classes of machining. Generating processes are of two types: in the first, the generating tool represents the form of the basic rack of the gear system and, in the second, the tool represents one of the gears of the system. A burnishing process also has been developed which smooths the profiles of machined gears by crowding them into accurate hardened-and-ground burnishing-gears. This process will make a good gear better, but it will not make a bad gear good.

Refinement of methods and reduction of cost are discussed, it being emphasized that the variable factor due to the differing human equations of the workmen who operate the production equipment is the greatest difficulty of any production problem.

GEAR production is, essentially, exactly the same problem as all other production problems. The requirements of the finished product must be determined first, and then suitable methods must be found or developed to produce the required results. Often, the exact requirements of the part or the product in question are not fully established until actual production has been under way for some time. This imposes on the production effort an additional burden of requirements not before known, and then supplementary requirements in the manufacturing operations. Such, in brief, has been the history of the production of almost every commodity.

The production of gears has been no exception to this common history. In many ways its difficulties constitute an extreme example; first, because I doubt if any one of us fully knows and exactly appreciates what all the essential requirements of this product are and, second, because the demands on the performance of gears are growing constantly more severe. The satisfactory gears of yesterday are not satisfactory today, and satisfactory gears of today may not be satisfactory tomorrow. In the third place, although many different methods of producing gears are now available, no one of them has yet proved itself to excel in all features; each has its advantages, and all have certain disadvantages.

The first essential for satisfactory production is suitable means of measuring the results obtained. We must be able to detect and measure definitely any troublesome errors before we are in position to correct them. Here again we are at a disadvantage in the production of gears. Many valuable and ingenious testing instruments for measuring the various elements of a gear have been devised; but, almost without exception, they are more nearly laboratory instruments than every-day shop testing tools. Such laboratory instruments have their place to fill, but production requires testing means that are simple, rapid and effective. However, until we know exactly what conditions in gears require continual watching, we are at considerable disadvantage when we attempt to evolve the facilities for testing them. This is the principal reason that such testing means have not yet made their appearance. Despite this lack of the first essential, production must be maintained; in fact, all production is more or less carried on in spite of inadequate information and equipment, rather than because of complete facilities.

MEANS OF PRODUCTION

Without knowing exactly what it is necessary to produce, we must proceed to consider ways and means for producing it. One thing we do know, however; it is that, on gears, very slight errors cause serious troubles. Small errors in profile or in spacing become very apparent to the ear when the gears are operated under load. In addition, as considerable sliding action exists between the gears, smoothness of profile is essential. Furthermore, as most of the gears used in automotive construction must carry high loads and often withstand considerable abuse, they must be hardened. Hence, the production department is called upon to meet a very high degree of precision under the most unfavorable conditions.

Many methods of machining gears have been devised, and they can be roughly divided into two general classes, forming and generating. The forming process is the older, and is represented by form milling the soft blanks and form grinding the hardened blanks. To obtain results by this method involves the difficult tasks of maintaining the proper form on the cutter or grinding wheel, and also of maintaining it in its proper position in relation to the blanks. The difficulties encountered here led to the development of various generating processes.

Generating processes can be divided into two general types: in the first, the generating tool represents the form of the basic rack of the gear system and, in the second, the tool represents one of the gears of the system. Here, as before, the form of the tool is of the utmost importance, but its position in relation to the blank has little influence on the profile of the gear produced except in regard to the thickness of the teeth. The hope that a generating process would be found to eliminate all trouble in the production of gears has never been realized. Generating has eliminated some of the difficulties encountered in the forming process, but it has also introduced a few difficulties of its own.

A burnishing process has been developed which smooths the profiles of machined gears by crowding them into accurate hardened-and-ground burnishing gears. This process will make a good gear better, but it will not make a bad gear good. One method after another has been tried to eliminate or minimize the difficulties of producing good gears. First one thing and then another has been blamed for the different troubles. More and more requirements have been introduced in gear-production methods. The accuracy of

[1] M.S.A.E.—Engineer, Niles-Bement-Pond Co., New York City.

the generating tools was questioned. As a result, these tools are now usually ground on the profile to correct them. Then the distortion in the gears due to hardening came in for the blame. As a result of this, machines to finish the profiles by grinding after hardening were introduced.

Refinement of Methods

Refinements cost money. The usual order of the day is to reduce production costs. Sooner or later this must be done, but it is a very difficult thing to refine the methods and reduce the costs at the same time. The final correct solution, if it is ever reached, must do this however. This reduction in cost may come from a reduction in the amount of scrap and salvaging charges. It may also come from the eventual development of a manufacturing process that produces better work with less productive effort. It has been done in the case of cylindrical surfaces by the development of cylindrical grinding machines, and a similar development may take place in the production of gears.

The introduction of gear-tooth grinding has not, of itself, cured all the troubles as yet. In the first place, most of these machines are made adjustable. This makes them very flexible in regard to the product, which is a very desirable feature in jobbing machines but a detrimental feature, in many ways, for production machines. Ease of adjustment makes it possible to correct faults readily, but it also makes it possible to introduce faults just as readily. Here the lack of simple and rapid testing-means is felt very strongly.

To my mind, the largest part of this and all production problems is the variable factor due to the differing human equations of the workmen who operate the production equipment. The modern plan of subdivision of labor tends to eliminate all interest on the part of the workman in what he is producing. This plan seems to be a necessary evil under present industrial conditions. At present, in the majority of cases, the amount of skill or technique required of an operator is relatively small. The production of the complex surfaces of gear teeth however, still requires considerable technique on the part of the operator if the best results are to be attained. This is particularly true of the grinding processes. At present, as much depends upon the machine operator as upon the machine.

Future Development

Production methods for gears are still in course of development. The wonder is that such good results have been obtained despite the many handicaps, rather than why the problem has not been completely solved. The subject of gears is receiving very wide attention at present. Private interests as well as engineering societies and trade associations are working hard to clear up many uncertain features. Considerable research is necessary before these difficulties can be cleared up. Meanwhile, the best course of procedure is to be sure that our designs give us the most favorable known conditions to meet; to make certain that our production equipment is maintained in the best possible condition; to discourage carelessness in the sharpening and shaping of tools, the mounting and handling of blanks and the like; and to insist on the best product obtainable.

AGRICULTURAL COOPERATIVE ASSOCIATIONS

STATISTICS gathered by the Federal Bureau of Agricultural Economics show that something over 12,000 cooperative associations in the United States are actively engaged in the marketing of farm products. These associations have a membership of over 2,000,000 farmers, and the amount of their business for 1923 approximated $2,200,000,000. This is from one-fifth to one-quarter of the total value of farm products marketed in the United States. Seventy per cent of these associations are located in the 12 North-Central States, which include the great corn and wheat producing areas. Six per cent of them are in the Pacific-Coast States. It is stated that the number of these associations has increased nearly 200 per cent since 1915, the membership increasing 300 per cent and the estimated amount of business increasing 300 per cent as measured in dollars. During the last 5 years the centralized or State-wide associations that combine the functions of the local and the federation have come into prominence. About 50 of these organizations now are operating throughout the Country, including 15 large cotton associations and 7 big tobacco associations.

It is difficult for the farmer to grade his own goods without going to serious expense. The marketing associations grade the products *into pools* and then merchandise *the pools*. These marketing associations are successful because they are based on economic necessity, perform definite services, are efficiently managed and enjoy the loyal support of their members.

In studying the methods practised overseas in marketing agricultural products it was found that the United States had much to learn from European countries. How Denmark set to work from the ground up to restore her country and how she became a cooperative commonwealth are matters of history. She began spreading vocational information among her people, and the farmers began intensive small-scale cultivation. Finding they could not raise wheat, they studied their soil and turned to making butter and raising hogs and poultry. Farms were enriched by scientific culture and the use of commercial fertilizers. They studied cattle breeding, dairying and the scientific raising of poultry for the market. Farmers did not work independently, but welded themselves into a great partnership in buying, selling and the spreading of valuable information. They went to work with careful and intelligent energy to capture the English butter, egg and bacon market from the Irish and succeeded. A great cooperative movement swept over the land and reached into every community until it embraced every phase of Danish agriculture. Today it is the dominant factor in the progress and prosperity of the nation, and Danish farmers enter world markets in a united group rather than as 205,000 individuals. Production occurs on individual farms, but distribution takes place through cooperative marketing. Approximately 90 per cent of the farmers in Denmark are enrolled in the agricultural societies, and more than 85 per cent of the farmers are members of cooperative creamery and bacon factory associations.

Cooperative organizations conducted in accordance with business methods have given agricultural marketing standing in the business world. They raise the standard of production and secure the economies that come from large-scale organization.—O. D. Foster in *Trade Winds*.

Steam Cooling

By ALEXANDER HERRESHOFF[1]

MILWAUKEE SECTION PAPER *Illustrated with* DRAWING AND PHOTOGRAPHS

ABSTRACT

PISTON friction is much the largest item of mechanical loss in an engine, amounting to fully one-half the indicated horsepower at light loads. Although opinions differ as to the most desirable temperature of the jacket-water for full-load operation, no question has arisen as to that for part load. It should be as high as possible, in order that piston friction can be reduced by keeping down the viscosity of the oil on the bearing surfaces, and that complete vaporization of the fuel may be secured. By reducing the friction of the piston and improving the vaporization, steam-cooling increases economy, which, on a number of cars of different makes, has been found to average 20 per cent more miles per gallon.

Water is practically a non-conductor of heat. Boiling water, or a mixture of water and steam, is far more effective for cooling than is water that is not boiling. Contrary to the almost universal belief, the extreme turbulence of boiling water enables it to absorb heat from three to five times as quickly as when cold. The failure of a water cooling-system, when boiling, is not caused by the inability of the boiling water to carry off heat, but by the fact that when steam has been formed it has no place to go and forces water out through the overflow.

In the steam cooling-system, the cylinder-block is merely a steam boiler that does not require forced circulation, will not burn out, so long as feed-water is supplied to replace that lost by evaporation, and remains at constant temperature. As dry steam is not essential, no dome or separating chamber is necessary. A working model of a steam cooling-system made possible an observation by the author of what goes on inside the jacket and the radiator while the engine is running.

Tests showed that crankcase-oil dilution can be reduced to any amount thought desirable by heating the crankcase, practically no dilution occurring if the cylinder jacket is maintained at 212 deg. fahr. Freezing can be prevented by the addition of alcohol, the percentage of which remains constant all winter because it is condensed and returned in the same manner as is the water. Other advantages of steam-cooling are said to include the use of a heater, for warming the car body, and freedom from odor, noise and fire hazards.

IN cooling an internal-combustion or heat engine, we are dealing with its fundamentals; and accurate control of the temperature of its working parts is necessary to get the highest efficiency. Although considerable difference of opinion has always existed as to the most desirable water-jacket temperature for full-load operation, no question has ever arisen as to the best water-jacket temperature for part load; it should be as high as possible, in order that the piston friction be reduced and complete vaporization of the fuel be secured. Piston friction is much the largest item of mechanical loss in an engine and, although its percentage of the maximum brake horsepower may be small, it amounts to fully one-half the indicated horsepower at light loads.

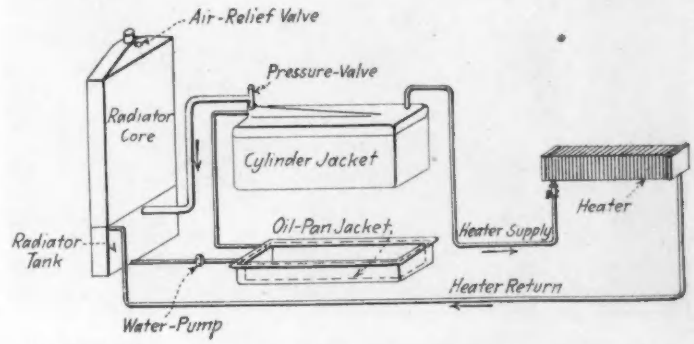


FIG. 1—"WIRING" OR PIPING DIAGRAM OF STEAM COOLING-SYSTEM
The Word "Wiring" Is Used because the Pipes Are about the Size of Fairly Large Wires

This friction loss can be materially reduced by keeping the cylinder-walls and the oil-film at a high temperature and, consequently, keeping down the viscosity of the oil on the rubbing surfaces.

When operating under full load, the heat of compression vaporizes any fuel particles entering with the intake and makes complete combustion possible. Under light loads the compression supplies little heat, and a hot combustion-chamber and cylinder-walls must be relied upon to vaporize the fuel. Even if the incoming charge has been highly heated and completely vaporized, it will condense and deposit liquid fuel on striking the cold walls.

With steam-cooling, the high temperature of the cylinder-walls at part load, by reducing the piston friction and improving the vaporization, produces better economy, which, in practice, has been found on a number of cars

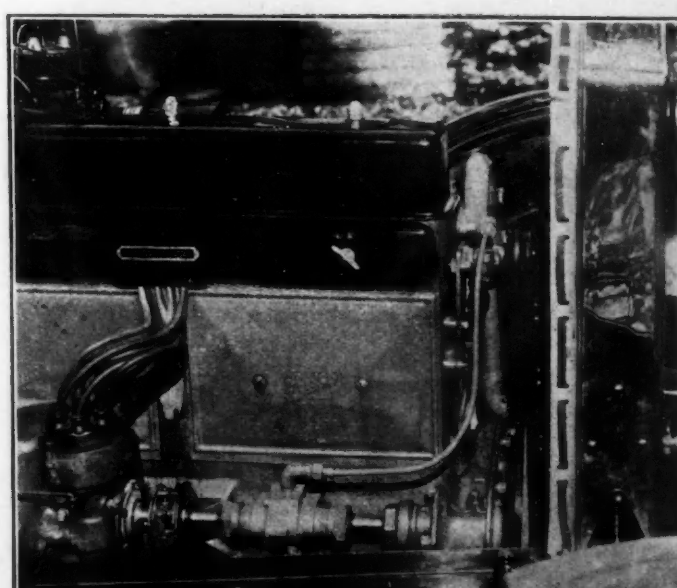


FIG. 2—STEAM COOLING-SYSTEM INSTALLED ON A BUICK CAR
The Water-Pump Is Small and the Piping of Neat Appearance. Twenty-Four Miles per Gal. of Gasoline Is Regularly Obtained with This Car

[1] M.S.A.E.—Manager, Rushmore Laboratory, Plainfield, N. J.

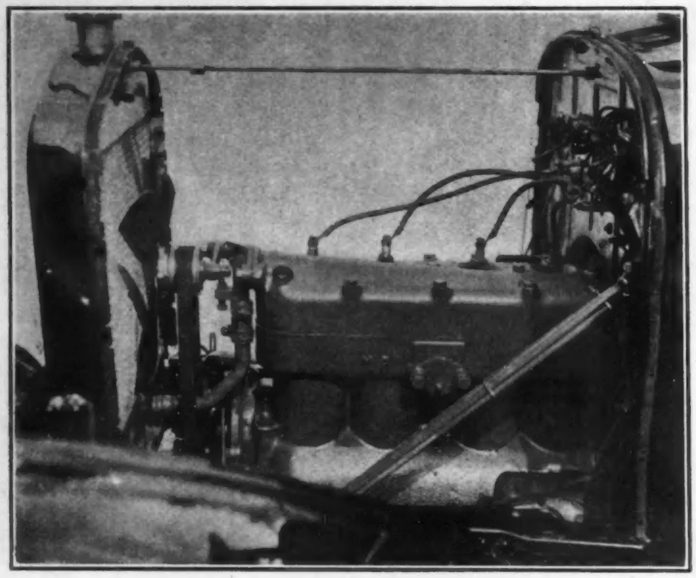


FIG. 3—FORD CAR EQUIPPED WITH STEAM COOLING-SYSTEM
The Combination Fan-Bracket, Steam-Outlet and Water-Inlet Castings Are Visible

of different makes to average 20 per cent more miles per gallon.

Most engineers have a "pet" temperature for the water-jacket, which ranges all the way from freezing to boiling. Such temperatures have been determined by full-load tests on the dynamometer. Unfortunately, these "ideal" temperatures are not maintained in practice for, unless the radiator is grossly too large, all cars will boil on a long hill or at just the time that the maximum horsepower is wanted.

Jacket temperatures for the maximum brake horsepower vary with the design of the engine and are influenced mostly by the amount of heat that the intake charge receives from the jacket before entering the cylinder. Ricardo in England and many investigators in this Country have shown that, if a fixed intake-temperature is maintained, the brake horsepower will increase with the increase of temperature of the jacket up to 212 deg. fahr., or as far as the observations have been carried. The curve, however, is nearly flat at this point so that an increase or decrease of a few degrees will make no appreciable difference.

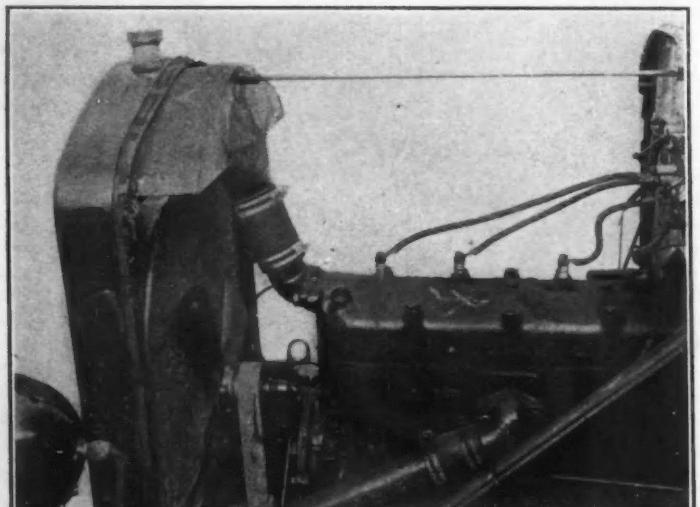


FIG. 4—FORD CAR EQUIPPED WITH WATER COOLING-SYSTEM
A Test Showed That the Temperature of the Water-Inlet Was 90 Deg. Fahr. while that of the Outlet Was Boiling

Experiments have shown that water is practically a non-conductor of heat. An electric flat-iron immersed at the top of a dish filled with water will cause the water near it to boil, while a piece of ice held at the bottom of the dish will melt only very slowly. As there are no convection currents and little conduction of heat through the body of the water, the ice will not melt for several hours. This illustration is taken from a lecture delivered at Cornell University in 1890 by the late George H. Babcock, inventor of the Babcock & Wilcox boiler.

STEAM-COOLING WORKING-MODEL

A working model of a steam cooling-system for internal-combustion engines has been made so that it is possible to see what goes on inside the engine jacket and the radiator while the engine is running. An electric immersion-heater of 300-watt capacity represents the cylinder and has 7 sq. in. of cooling-surface, making the rate of heat-transfer 2.5 B.t.u. per sq. in. per min., which is comparable with a rate of from 3 to 5 B.t.u. per sq. in. per min. in an internal-combustion engine at full load.

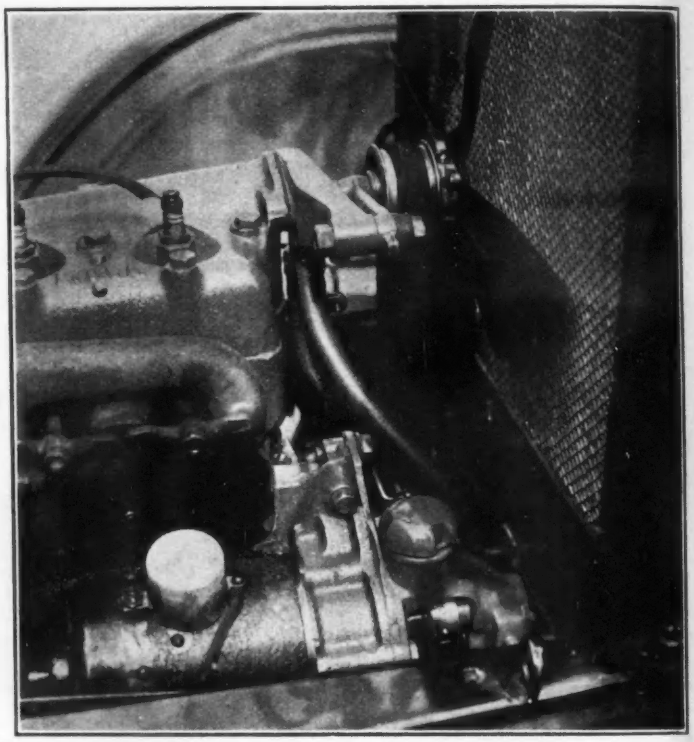


FIG. 5—WATER-PUMP INSTALLED ON A STEAM-COOLED FORD CAR
The Combined Fan-Bracket, Pipe Fitting and Piping are Easily Seen

In the model, the radiator is placed above the engine, so that the condensate is returned to the tank by gravity. The cycle is as follows: Steam is delivered from the engine jacket to the reserve water-tank at the bottom of the radiator, rises into the core and is condensed. The condensate drops back against the up-flowing steam and falls, boiling hot, into the tank from which it is returned to the cylinder jacket by gravity; and the cycle is repeated. As the radiator core contains no water and only air or low-pressure foglike steam, it is practically immune from leakage and from the deposition of sediment, as well as from freezing, when working in very cold weather.

With the cooling element between the cylinder jacket

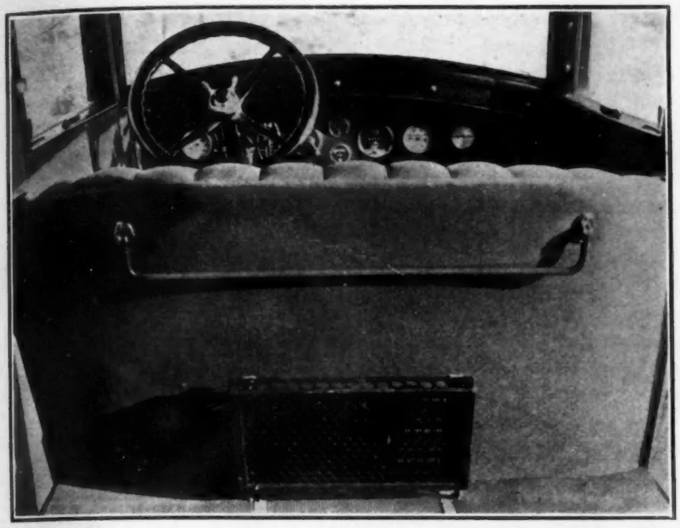


FIG. 6—STEAM BODY-HEATER INSTALLED ON A BUICK SEDAN
Although Occupying a Small Amount of Floor Space, Its Size Is Sufficient to Keep the Temperature of the Body at 70 Deg. Fahr. When the Outside Temperature is 0

and the filling opening, it is possible to run continuously without loss of steam with the filler-cap removed. This allows water to be added while the engine is running, just as in the usual system that uses water as the cooling agency. In fact, the only objection to always running with the cap off is that, if the engine is stopped suddenly, after running under a heavy load, a small amount of steam would be discharged from the filler opening for a few moments and would give a bad impression. The actual water loss from so momentary a discharge of steam would be negligible. A small spring-loaded relief-valve having a slotted seat to allow free in-and-out passage of air is used to prevent a heavy discharge of steam. The valve is usually set at 3 lb. per sq. in. although the pressure upon stopping rarely goes above 1 lb. per sq. in. This relief-valve has no other function and has nothing whatever to do with the working of the system.

The average water cooling-system, when mounted on a dynamometer and cooled by fan-blast only, will carry less than one-half the maximum brake horsepower continuously, whereas a steam cooling-system will always deliver the maximum brake horsepower continuously, even if the capacity of the radiator has been exceeded, the excess heat being dissipated by blowing off dry steam through the air-relief valve. Such operating conditions are often duplicated on a long hill with a following wind, when the water cooling-system breaks down, blowing off large quantities of water, and the engine refuses to pull, so that the driver has to wait for the engine to cool off and must refill it before going on. With steam-cooling, if the capacity of the radiator is exceeded, the only result is a slight blowing-off of steam. The engine functions as usual, not being influenced at all by what happens to the steam after it has left the jacket. In short, the radiator has nothing whatever to do with the engine. It is merely a water economizer.

COOLING EFFECTIVENESS

Boiling water, or a mixture of water and steam, is far more effective for cooling than water that is not boiling. If we refer to some work done long ago in connection with steam boilers, we find that the heat-transfer per square inch per degree of temperature-difference is from three to five times as great with boiling water as with cold water. The failure of a water cooling-system when boiling begins is not caused by the inability of the boiling water to carry off heat but by the fact that when steam is formed it has no place to go and forces water out through the overflow until the the water level in the jacket is below some part of the cylinder, which, consequently, becomes abnormally hot. The action is somewhat like that of a coffee percolator with its top removed; the water passing up through the tube does not drain back and is finally ejected.

Contrary to the almost universal belief that boiling water will not absorb heat so quickly as will cold water, the extreme turbulence of boiling water enables it to absorb heat from three to five times as quickly as will cold water. This is the vital point in all discussion as to the merits of steam and water cooling.

The cylinder-block is merely a steam boiler, which, as we all know, does not require forced circulation and will not burn out so long as feed-water is supplied to make up for the loss by evaporation. As in a steam boiler, heat is removed by the steam passing off; the temperature of the boiler is constant, depending upon the pressure, in this case, atmospheric pressure. A boiler is used to generate dry steam, therefore a steam dome, or "separating chamber," is used to separate the water from the steam. In a steam cooling-system it makes no difference whether the steam is wet or dry; and no steam dome is necessary.

As the water that is boiled off must be replaced and the relative positions of the radiator and the engine on a car are such that the water will not flow back, a pump is necessary to lift the water from the reserve tank into the cylinder jacket. At low speeds, a so-called centrifugal pump will not lift water to even this small height; so, a gear-pump is used. To supply the evaporative requirements in the average engine, only 0.07 lb. per b.hp. per min. is required. In practice, the pump is made to deliver from two to three times that amount, which is less than the amount of oil usually circulated.

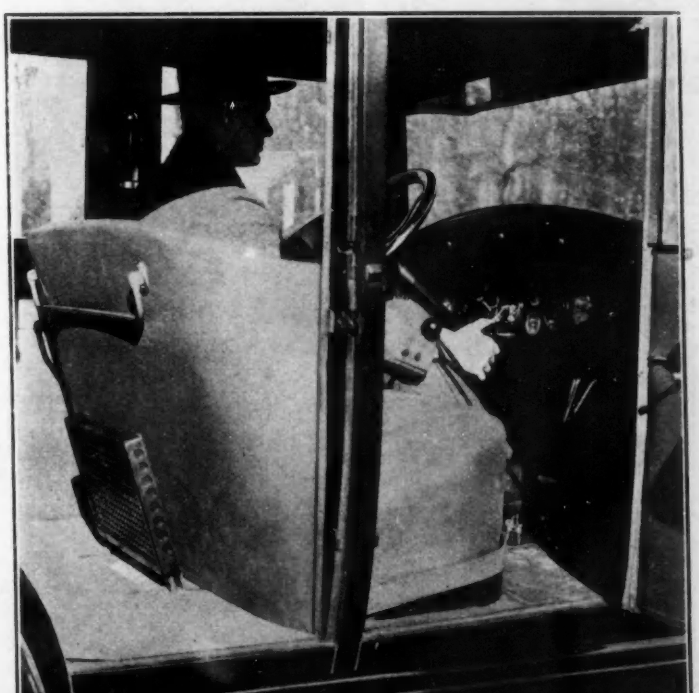


FIG. 7—CONTROL-VALVE FOR BODY-HEATER ON INSTRUMENT-BOARD OF BUICK SEDAN
The Amount of Heat given Off by the Heater Is Entirely Controlled by This Valve and Is Independent of the Power Developed by the Engine

Such a gear-pump when made with fine-pitch helical-tooth gears of stainless steel will outlast the engine and be noiseless. The power consumed is very small. Excess water pumped into the jacket flows out with the steam to the radiator.

Reduction of Crankcase-Oil Dilution

Crankcase-oil dilution is not a problem, as in water cooling, for the amount of dilution can be reduced to any degree thought desirable by using crankcase heating in connection with steam-cooling. Many tests have shown that practically no addition of diluent occurs when operating under full or part load, if the cylinder jacket is maintained at 212 deg. fahr.; but a small quantity of condensed fuel finds its way into the crankcase whenever the engine is started cold. The accumulated diluent can be driven off to almost any degree by jacketing the oil-pan and passing water at 212 deg. fahr. through the jacket. This jacket, although heating the oil and driving off any condensed fuel at light loads, will act as a cooling-jacket under heavy loads and will remove heat from the oil. This is important, for many engines run with the oil far above the proper temperature.

To prevent freezing in a cold garage, or when standing for long periods in cold weather, alcohol is used. Unlike the usual water cooling-system, alcohol is not lost with steam-cooling, because the alcohol is condensed and returned to the jacket in the same manner that steam is condensed and returned. In actual practice, it has been found that the percentage of alcohol is maintained constant all winter.

Steam-Heated Body

An interesting by-product of steam-cooling is the steam heater for the body. The body heater consists of a number of 3/8-in. finned tubes soldered into headers and connected between the cylinder jacket and the radiator by 3/8-in. tubing, so that part of the steam from the jacket goes through the heater. The amount of heat given off from the cylinder jacket, under all conditions, is many times more than can ever be used for heating the body. Tests have shown that the heat-loss from the cylinder jacket, while idling, is fully 15 per cent of the loss when under full power and all this heat can be transferred into the body. With an exhaust-heater, the result is different, for not only does the heat in the exhaust vary greatly with the load, but the heat-loss from the exhaust-pipe before it enters the body is so great that under idling or light-load conditions practically no heat is conveyed to the body.

Obviously, steam-heating introduces no objectionable odor, noise or fire hazard. In practice, the constant supply of abundant heat under the control of a small valve adds greatly to the comfort of passengers and must be experienced to be appreciated.

Fig. 8—Cadillac Car Equipped with Steam Cooling-System
Note the Absence of a Radiator Tank, a Top Tank Being Unnecessary with Steam-Cooling

THE DISCUSSION

A. G. Herreshoff:—Fig. 1, the piping diagram, shows the radiator core, the air valve and the radiator lower tank enlarged to carry reserve water. We are enabled to reduce the size of the core, for operating at a higher temperature; the radiator is more efficient than in water cooling-systems and the area can generally be reduced 25 or 30 per cent.

The diagram shows the oil-pan jacket and body heater which, of course, need not be used. The water flows to the pump and is pumped through the oil-pan jacket into the cylinder, where it is converted into steam. The pressure-valve is set to open at 1 or 2 lb. per sq. in. The steam formed up to that pressure goes through the heater, so that all the heat that is given to the jacket is forced into the heater immediately and the body of the car can be heated very quickly.

Fig. 2 shows a Buick Standard Six that we have equipped with our system. The large centrifugal pump has been replaced with a small gear-pump. The pipe that feeds water to the engine is of 1/4-in. outside diameter and 3/16-in. inside diameter. Water is fed into the cylinder through the same casting from which the steam passes out. This is done purposely so that, when the engine is started cold, the cylinder jacket acts like a tank and the water, being fed in next to the overflow, passes out without causing any circulation in the cylinder-block; therefore, only the stagnant water in the cylinder-block need be heated.

A Ford car equipped with steam-cooling is shown in Fig. 3. The elevated position of the fan and the steam pipe can be seen. The fan bracket, steam pipe and water connection are combined into one casting.

A regular water-cooled Ford is shown in Fig. 4 for comparison. The presence of the water pipes on the water-cooled car is noticeable.

Fig. 5 shows the water-pump in the Ford car. The front cover-plate is machined off just forward of the generator driving-gear; the small casting that combines the oil-filler and pump is bolted on, and a driving-disc is forced into the recess in the generator driving-gear, which has a square hole and drives the pump. This pump is of 1-in. pitch-diameter, the gears being 5/8 in. long.

Fig. 6 is a view of a body-heater installed in a Buick car. The heating-tubes are placed one above another so as to occupy as little floor-space as possible and are protected by a perforated metal guard.

Fig. 7 shows the valve for the heating system on the dashboard. The turning on of the heat is easily accomplished without reaching down.

A view of a 4-year-old Cadillac that has been driven some 30,000 to 40,000 miles is shown in Fig. 8. The

radiator has no top tank as this is not necessary with steam-cooling.

Again referring to the steam-cooling model it can be seen that the passage of water by the heating element is much quicker than even with forced circulation. As a matter of fact, all cars now are steam-cooled, whenever a large number of British thermal units per square inch is being dissipated. What actually happens is that steam is generated at every hot-spot such as a valve-seat, but in passing off mingles with cold water in the rest of the system and is condensed before reaching the surface of the water. The water goes through the radiator, is cooled, returned to the jacket and condenses more steam. The surging of the water discharge from the jacket is a proof that this condition exists.

President H. L. Horning:—I look for the time to come when we shall not have radiators. This has been demonstrated by Mr. Herreshoff, who has shown how little radiator capacity is really needed and how the water and the steam can be circulated around the oil-pan, heating the oil and cooling the steam there also; and that we can heat the car with it, and might heat the incoming charge in the intake-manifold. With these increasing efficiencies, I am in doubt whether the radiator, as we know it, will be necessary. It seems very probable that we can take this fragile device off the front of the car and compress it into a more efficient form. A little slot approximately 4 in. wide and about 27 in. high, on racing cars, will take air into it and we can have a very efficient steam cooling-system with the fins arranged in the most effective manner around this tube. Steam-cooling makes it possible for us to concentrate the radiator into a very small space.

A very important thing, to which Mr. Herreshoff has called attention, is that one-half the power developed in the engine is consumed in overcoming friction, particularly at the usual running-speeds of engines and cars. In a well-known taxicab, my company demonstrated the fact that, at a speed of 20 m.p.h., of the 10 i.hp. generated in the cylinders, 5 hp. was required to drive the car; one-half the power, therefore, went for car and other losses. When we get up to full load, we are doing well if we have but a 15-per cent friction-loss; the useful power runs from 50 per cent at the usual loads up to 85 per cent at full load. That is an enormous "overhead," as we might call it.

As has been often related the literature on the subject shows, when friction losses in an engine are analyzed, that between 50 and 60 per cent of the power is lost in shearing the oil-film on the cylinder-walls. You will be surprised to know that pressures within the oil in the neighborhood of 5000 lb. per sq. in. are generated as the pistons try to run through that oil-film. The film is practically incompressible and very stable.

We all know that oil is stiff and thick in cold weather. When the oil warms up, it becomes thin, and the power lost is less when it is thin. In a steam cooling-system, the oil-film has a viscosity that consumes less power. That is very important at low loads and at low speeds.

In a 3-months fuel-efficiency test 2 years ago, more than 115 ton-miles per gal. was made with a steam-cooled engine. When we took the engine out, retaining the steam-cooling system and the carbureter setting that had proved best for road work, we found that, from 600 to 1600 r.p.m., the variation was only 0.03 lb. per hp-hr., the maximum being 0.53 lb. per hp-hr. at 1600 r.p.m.; 0.50 lb + at 1000 r.p.m., and only 0.50 lb. at 600 r.p.m. If this had been a water cooling-system the story would have been entirely different; the results would have been much higher, about 0.70 lb. at 600 r.p.m., on account of the lower temperature.

It is now generally known that the indicated horsepower remains steady, irrespective of the load. The fact is, that at high load and high temperature the friction horsepower loss is less, and at low load and low temperature the viscosity is high; the actual horsepower loss is higher. It is an increasingly difficult thing to get high economy at low loads and low speeds; but the steam cooling-system seems to go a long way toward helping the economy at low loads.

As Mr. Herreshoff has pointed out and as was well developed in the fuel tests made at the Bureau of Standards under the direction of the Society, crankcase-oil dilution is almost a thing of the past when the temperatures of the cylinder-walls and of the oil-pan are kept up.

The wonderful thing about steam-cooling is the fact that it maintains a uniform temperature of 212 deg. fahr. and has a very fortunate relation to the temperature that must be maintained to vaporize fuel. We know that most of the fuel is vaporized in the cylinder, anyway, because there is not time for it to be vaporized in the manifold; neither has the manifold sufficient surface nor temperature for vaporization there. The cylinder has all these elements: greater surface than the intake-manifold, the time-element is many times greater, and the temperature, of course, is much higher; in short, the chance of vaporization is many times greater in a cylinder than in a manifold. This ability of the steam cooling-system to maintain a uniform temperature is very natural. Engine tests were run when the atmospheric temperature was about 90 deg. fahr., and it took practically 4 hr. to burn up 1 gal. of gasoline. With the same carbureter-setting, when the temperature was 5 deg. below zero fahr., the difference in the time required to burn up 1 gal. of gasoline was only 4 per cent and the engine idled for practically 4 hr., never skipping during that time. This was an excellent demonstration of the steam cooling-system.

As Mr. Herreshoff has pointed out, all so-called water-cooled cylinders are steam-cooled. No engine can operate without steam-cooling, and all our make of engines have cooled themselves by steam.

As engineers, we should take more advantage of the known laws of heat. The demonstration of the bad cooling-qualities of the water, in the experiment in which the ice melted very slowly when held on the bottom of the glass bowl and the water around this portion was so cold that it condensed the vapor on the outside, shows what a bad conductor of heat water is. At the top of this bowl you noticed the flat-iron in the water near the surface and that the water at this depth was boiling, yet the ice at the bottom was melting very slowly. This all illustrates the laws of physics which we all should know for they really govern our climate and seasons.

Our company used the steam cooling-system all last winter in a motor car and obtained satisfactory results. It took but a very short distance or time to warm-up and operate properly and with little use of the choke. The engine is kept in a cold garage.

Steam-cooling offers one of the best solutions of the problem of temperature differences in cylinders. An engine that would knock hard with a water cooling-system at 192 deg. fahr., would not knock when the steam is coming off at 212 deg. fahr. We can account for that on the grounds that with steam-cooling we lower the temperature of the maximum-temperature points and raise the temperature of the minimum-temperature

points and yet raise the average temperature. High-temperature points seem to be fewer, and they are the ones that caused the knocking. By keeping cylinder temperatures more uniform, the distortions are less. It will take a long time before we learn just how important that fact is; it seems to be one of the advantages of the steam cooling-system.

W. S. NATHAN:—Can Mr. Herreshoff give the relative cost of a steam-cooling installation as against that of a water cooling-system with a centrifugal pump, one of the ordinary type?

MR. HERRESHOFF:—A saving in first cost ranging from only a slight amount in a thermosiphon system to $25 in one well-known eight-cylinder car in which two large centrifugal pumps with thermostats weighing 32 lb. are replaced by one gear-pump weighing about 4 lb. is always effected as well as a considerable saving in the radiator core on account of its smaller size. The reason is that the cooling effect of the radiator core is dependent upon the air-blast and the difference in the average temperatures of the water and the air. If we consider that in a water cooling-system the water leaving the cylinder-jacket has a temperature of 150 deg. fahr. and that the drop in the radiator is 20 deg., which is fairly common, the water entering the jacket will be about 130 deg. fahr. and the average will be about 140 deg. fahr.; if we assume the temperature of the atmosphere to be 100 deg. fahr., the difference in temperature would be 40 deg. fahr. Comparing this with a steam cooling-system, whenever the radiator contains steam, the temperature of the core is 212 deg. fahr.; so, the difference in temperature will be 112 instead of 40 deg. fahr. These figures show that less than one-half the core is necessary. If a little higher water-cooling average-temperature were taken, say about 180 deg., the saving would be about 30 per cent.

Another important thing is that when the capacity of the radiator has been exceeded in a steam cooling-system, steam quietly passes off through the air-relief valve and no harm is done beyond a very slight loss of water. One pound of water lost in the form of steam will carry off about 10 times as much heat as will 1 lb. of water lost in the form of water at 212 deg. fahr.

What actually happens in the water cooling-system is that, as steam is formed in the jacket, it simply forces water out; it will force the entire contents of the top tank of the radiator out through the overflow; then the engine will simply be running without enough water. As steam is formed, it has no place to go but out through the overflow tube. The action is so rapid that considerable water is carried off by the steam. The radiator cannot condense the steam as it is full of water or air and the steam cannot reach the cooling surfaces.

With steam-cooling, the steam forces the air out through the relief valve but rises only as far as is necessary for it to be condensed. After it has condensed, it drops back to the tank. When the engine is running under part load, only the bottom 2 in. or so of the radiator is hot but, as the load increases, the hot surface increases automatically, the condensing area varying directly with the load.

In a water cooling-system, a blanket or film of stagnant water is next to the heating surface, or outside the cylinder-wall. The heat must penetrate this blanket and at a loss of a considerable number of degrees. The number of degrees will vary with the rate of heat-transfer. At 5 B.t.u. per sq. in. per min., the difference in temperature between the outside of the cylinder and the water in the jacket will be about 50 deg. With steam-cooling, this jacket-water does not exist, because the jacket-water itself is what is turned into steam and dissipates the heat; so, the heat is taken away directly from the surface instead of through a jacket of water around the cylinder which acts to a greater or less extent as an insulator.

F. M. YOUNG:—If the radiator could be raised sufficiently high on the chassis so that it would be above the top of the water in the engine, would not the pump be unnecessary?

MR. HERRESHOFF:—Yes.

MR. YOUNG:—In that connection, it would probably be interesting to know that some 12,000 or 15,000 farm lighting-outfits of a well-known make that were originally manufactured in 1919 and are still being made with success, are in use. I think they could be considered under the subject of steam-cooling. An improved radiator location will play an important part in steam-cooling.

A. W. POPE:—Everything that Mr. Herreshoff has said has been demonstrated in my Ford that has a gravity steam cooling-system, especially his remarks about the small water-loss from a leaky radiator. If the radiator is placed above the water level, the leakage is very slight.

MR. YOUNG:—Did you put yours up high?

MR. POPE:—Yes; it is in a horizontal position over the engine, tilting back a little. The steam rises to the front tank, goes back into the core, is condensed, and flows down into the bottom of the cylinder jacket by gravity. In November, I put 2 qt. of water and 2 qt. of alcohol into the cylinder water-jacket and have not looked into it since. Although the radiator is very leaky, it loses practically no alcohol. I suppose that, if I drove very much with full power at low speed, I could boil it out. The radiator has no fan. The air seems to go up through the radiator and "do the business" so long as the car speed is above 10 to 15 m.p.h.

MR. HORNING:—That is one reason that I said that I thought we should not have radiators. Mr. Pope uses no fan and used only 2 qt. of water and 2 qt. of alcohol all winter. The radiator lies horizontally.

MR. HERRESHOFF:—If you examine the Babcock demonstration apparatus with a light placed behind it, the different temperatures are shown by the refraction of light; next to the iron you can see the stratum of hot water.

Last winter, at the laboratory in Plainfield, N. J., I showed Mr. Horning an experiment that demonstrated what happens in regard to the rusting of an automobile cylinder when the engine stops with cold water in the cylinder jacket. I took two little cast-iron cups, polished the outsides and then wiped the outer surfaces with oily waste so that they were covered with a film of oil. Into one of the cups I poured cold water and into the other, hot water. The cups were then covered in a pan that contained a small amount of hot water to form vapor. In about an hour, the cup that had contained the cold water was red with rust; the cup that had contained the hot water would not rust if you were to leave it there and not disturb it for 3 days or a week. The conditions are similar to those in a cylinder with a certain amount of moisture, mostly produced by the products of combustion. If the cylinder-wall is cold when the engine stops, the moisture or steam will be condensed on the cold walls and, for some reason that we do not understand, very active rusting is produced even though an oil-film covers the surface. This experiment bears out

an article written by Frank Jardine[2] with regard to the rusting of cylinders and the development of aluminum pistons.

MR. HORNING:—I am not so much interested in why this rusting takes place as that it does take place. In fact, we know that the analyses of oil show that a certain amount of rust is present after a little use. Some persons like to point out that this rust and this rusting are the causes of very rapid wear. Undoubtedly, it is not beneficial. I can testify that our men in the testing-room are very familiar with this rusting; very often, when they take off a cylinder-head after the engine has stood all night, they find the finely ground surface of the cylinder-wall rusted and have often wondered why it was so. The answer seems to be that the cooling water was relatively cold.

During the time that the cup of cold water is standing and the whole system is cooling, moisture is condensing, of course, on the surface of the cup, a much greater amount of moisture than on the cup containing hot water which shows no tendency to condense water on its surface.

In a motor car, identically the same condition exists. If the engine were stopped when relatively cold, it would cool off immediately and the walls would condense moisture; whereas, if the walls were at a temperature of 212 deg. fahr., the tendency to rust would be much less.

MR. HERRESHOFF:—The steam-cooled cars that we have run show very little wearing of the cylinder-walls.

MR. HORNING:—What is the viscosity of the oil used in the steam cooling-system as compared with that of the water cooling-system?

MR. HERRESHOFF:—We use a medium oil exclusively.

MR. HORNING:—Does the steam cooling-system seem to produce greater disintegration of the oil under the piston-rings and on the piston walls?

MR. HERRESHOFF:—No; we have not noticed that.

MR. HORNING:—Is it better or worse than the water-cooled system?

MR. HERRESHOFF:—The oil appears to keep remarkably clean and clear. In the case of two cars, of different makes, one with a steam-heated oil-pan compared with one without; the oil in the one with a steam-heated oil-pan, after covering 2000 miles, and standing for a few days, appeared yellow; whereas, in the car without the steam-heated oil-pan, the oil was black and inklike; but, possibly, this may be due to some other cause.

CHAIRMAN J. B. ARMITAGE:—The desirability of steam-heating the cars and motorbuses in winter would seem to be sufficient to warrant the use of the steam cooling-system.

MR. YOUNG:—Do you not have rust around the filler-cap because the radiators boil over?

MR. HERRESHOFF:—They always boil.

MR. HORNING:—Did not that particular car boil because they wanted it to become as hot as possible? They wanted it to get as near steam-cooling as they could, then stop and let nature take its course.

MR. YOUNG:—They took into consideration, too, a construction that was of an ironclad type; it was more of a boiler than a cooler.

MR. HERRESHOFF:—That construction was dictated by experience some years ago when the modern type of radiator was not so well made as it is now; the core then used was of an air-tube type but the construction was not identical with the sample that has been shown. The company that built these motorbuses keeps an accurate record of its vehicles that are used in New York City. When cold weather comes on in the fall, a radiator cover is fitted; on the day the covers are fitted the mileage per gallon of the whole fleet immediately rises. It drops off in cooler weather and rises again when partly covered to maintain the temperature as high as it was during summer weather.

MR. YOUNG:—In the construction of engines, is it your opinion that the coring of the steam compartments, or what are now known as the water compartments or jackets, should be arranged in a particular way, so as to get cooling around the valve? Do you think the system is adaptable to any engine now built?

MR. HERRESHOFF:—Absolutely no change is needed.

MR. YOUNG:—Not with multiple cylinders?

MR. HERRESHOFF:—No.

MR. POPE:—In some cases, with a water cooling-system, it has been advisable to direct the cooled return water against some local hot-spot. It improves the operating condition of the engine. With a steam cooling-system, how can these hot-spots be cooled as effectively?

MR. HERRESHOFF:—A steam cooling-system has no one hot-spot. With a water cooling-system a different temperature-drop occurs in the water-film, depending upon the amount of heat per square inch that is given off. When the amount of heat per square inch is high, a considerable difference in temperature exists between the iron and the water. The high velocity of the water when directed against a hot-spot will reduce the thickness of the water-film and so reduce the temperature-drop. Two makes of car that I know of put the intake water directly under the exhaust-valve seats; in that way, the water, impinging, brushes off the film and gives more effective cooling.

MR. POPE:—Before they directed that water in there, they had steam-cooling under the valve-seat?

MR. HERRESHOFF:—Yes; but in some cases the pockets are associated with the cylinders and adjacent pockets so that a steam-pocket is formed. A steam-pocket does not occur in a car unless the steam cannot get out and no water can get in. You might call it an air-pocket. As the jacket fills with water, the air cannot get out; so, the water cannot get in. In one engine that we were steam-cooling, I found a bad condition of that kind, because the hole between the cylinder and cylinder-head had not been drilled.

[2] See *Automotive Industries*, July 31, 1924, p. 243.

Engine Reconditioning—Refinishing of Cylinders and Aligning of Shafts

By ROBERT C. MCWANE[1]

SERVICE MEETING PAPER

ABSTRACT

THE best engineering talent of the automotive industry has been principally devoted to perfecting the design and to the more accurate production of automotive engines; too little attention has been given to reconditioning such engines when they have become worn after rendering thousands of miles of service. Rubbing surfaces will inevitably wear at the high speeds at which automobile engines operate, and warpage of the engine block occurs as the result of the unequal cooling strains in the intricately cored cylinder castings.

It is almost criminal for anyone who lacks a knowledge of elementary mechanical engineering principles and micrometer experience to take down and attempt to reassemble a machine built with such exactness as an automotive engine. Successful reconditioning of such an engine depends upon the utmost exactness in aligning or squaring each part with all the others, starting with the cylinder base-line of the crankcase as datum and securing perfect parallelism with that base of the crankshaft and the camshaft, the main bearings, connecting-rod bearings, piston-pins and camshaft bearings, and squaring the cylinder bores and the connecting-rods at perfect right angles to the base line. An error at one point cannot be compensated for at another point. Refinishing worn cylinders, fitting new pistons, line-boring and fitting bearings and bushings, grinding and realigning crankshafts and similar work call for operations and tolerances measurable in thousandths and even in ten thousandths of an inch. This necessitates the employment of special precision instruments and special machine-tools and a knowledge of their proper use.

The major operations of reconditioning an engine, following the preliminary washing and complete taking down of the engine and the examination and checking of the parts with micrometers, surface plates, dial gages and test indicators, are described. Methods of refinishing cylinders, as boring, reaming, honing and grinding, are also described and attention is directed to the difference in application of these methods in the factory and in the reconditioning shop. Use of a heavy-duty cylinder-grinding machine is recommended as the only method that is capable of restoring the original trueness of the cylinder bore with the base of the cylinder-block and satisfactorily and economically correcting worn and warped cylinders with the minimum loss of metal and of producing a finished surface equal or superior to that produced by any other method.

The importance of keeping the crankshaft in perfect condition is emphasized, but the reconditioning of a shaft that is worn or out of alignment should never be attempted by filing, turning, lapping or polishing. Crankshaft grinding requires extreme care and satisfactory results can be obtained only by the use of machines built especially for the purpose. The most exacting part of a reconditioning job is the fitting of the main and connecting-rod bearings, and the best engineering practice calls for the use of a type of universal equipment having a cutter-tool bar that can be adjusted with micrometer accuracy. When a crankshaft has been reground, new undersize main bearings should be used, as otherwise the timing-gear centers will be changed and the pitch line of the gear train disturbed, causing the gears to jam and become noisy.

The difference between fitting bearings into a new crankcase and into an old one is great. To compensate for wear and warpage in an old one, the bearing halves should be left from 0.002 to 0.003 in. above the crankcase and cap faces, so that when bolting the cap on the case the bearings will have a drive fit. Other operations in fitting and boring the bearings are explained. The fitting of timing-gears, camshafts, idler gears and their bushings and water-pump and magneto shafts and the putting into mechanical order of the valve push-rods and adjusting screws require as great precision as the major operations, but are not discussed in detail.

It is false economy to try to refinish worn small parts that can be replaced at less cost than the labor necessary to make the old ones serviceable. The old parts will not give the service that may be expected from new ones.

SUCCESSFUL reconditioning of automotive engines presupposes a more or less thorough knowledge, on the part of the reconditioner, of the design of the engine and of the manufacturer's methods of securing such a close approximation to perfect condition in the new machine. The words, "perfect condition" are used advisedly, for that is the constant aim in the production of the automobile engine, the world's greatest monument to engineering brains and mechanical skill.

It is, therefore, highly reprehensible, if it does not border on actual criminality, for any man unschooled in the most elementary principles of mechanical engineering, and possessed of no micrometer experience or equipment, to pull down and attempt to reassemble a machine built of parts finished to such exact sizes as those making up an automobile engine. Unfortunately, up to this time the industry's best engineering talent has been devoted solely to the design, perfection and production of automotive engines, and too little attention has been given to the problem of reconditioning such engines when this becomes necessary, for it must be recognized that rubbing surfaces, moving at the high speeds essential in a machine of this type, will inevitably wear.

As cylinder wear is not the only condition with which we have to deal in an automobile engine that has given many thousands of miles of service, I shall discuss the subject of reconditioning somewhat broadly, because unless all the bad conditions in an old engine have been corrected, it cannot properly be said that the engine has been *re*-conditioned. For this reason, any operation that goes no further than the resizing, or refinishing, of worn cylinders should not be recognized as engine reconditioning. This brings us logically to the removal of the engine from the automobile, truck or tractor and its complete disassembling for inspection and check-up.

[1] Chairman of the Membership Committee, National Motor Regrinders' and Rebuilders' Association, New York City.

Cleaning and Examination of Parts

Since the presence of dirt, grime and grease furnish little inspiration for painstaking and accurate workmanship but, on the contrary, greatly decrease the efficiency of even the best mechanics, the first operation should be a thorough washing of the engine by its complete submersion in a tank of hot water and washing soda, or any one of the several excellent washing solutions marketed under well-known trade names. The engine should then be mounted on a universal engine-stand and completely dismantled. Then the separate parts should be washed again to remove all traces of grease and oil. At the same time, all oil lines in the crankcase and crankshaft should be blown out and thoroughly cleaned. A careful inspection and check-up should then be made of all parts that are subject to warpage or wear. Only by such a procedure can the conditions requiring correction be determined, and this inspection work should always be done by a capable mechanic, skilled in the use of micrometers and other precision instruments. It is assumed, of course, that every shop attempting the reconditioning of automotive engines is equipped with a full set of precision measuring instruments, such as inside and outside micrometers, surface plates, dial gages and test indicators.

The cylinder-block should be examined for cracks, tested for warpage of its base and measured for wear of the cylinder bore and valve guides. Cylinder wear in excess of 0.003 in. at any point of the bore calls for a resizing operation, which will be discussed in detail later, and appreciably worn valve guides should be listed for replacement.

Checking the Crankshaft and the Crankcase

The crankshaft, after the flywheel has been removed, should be put between centers to check the trueness of the flange and to determine whether or not the shaft is sprung. Main bearings and connecting-rod or crankpins should be measured for amount of wear, or indicated with a dial or special test-indicator. Crankpin bearings that are out-of-parallel with the main bearings throw the connecting-rods out-of-line, causing them to whip back and forth between the piston-pin bosses, producing probably 50 per cent of the noise usually attributed to piston slap. This lack of parallelism can best be determined by the use of a special crankshaft testing-machine, with parallelograph attachment, which draws a picture showing the exact condition of the pins relative to the main bearings.

The crankcase should be checked up for cracks, alignment and warpage of the base. All cylinder-block and journal-bearing studs should be examined for poor threads or looseness in the crankcase. Camshafts, camshaft bushings in the crankcase, timing-gears, idler gears, idler-gear studs, idler-gear bushings, and magneto and water-pump-shaft bushings should be checked to determine whether new ones are required. Connecting-rods should be examined for fractures and all bolts and nuts should be given special attention.

Worn timing-gears are always more or less noisy, and, while the old ones may frequently be used in a reconditioning job, this should never be done without a clear understanding with the owner, who may not place as high value on quietness as is represented in the cost of new gears. Idler-gear studs may be saved by grinding off 0.002 in. from the outside diameter, as the new bushings usually have enough metal inside to allow for an undersized stud. It is never satisfactory to use an old pump-shaft and pump impellers; these should be replaced on every job.

Methods of Sizing and Finishing Cylinders

While waiting for replacement parts that have been ordered immediately following the checker's report, we can proceed with the work of resizing the worn cylinders and the crankshaft. So much has been written in recent years on the relative merits of the grinding, honing, boring and reaming methods of cylinder resizing and refinishing that it would seem that very little can be added to the discussion. Boring was the original and, for some time the only, method of finishing engine cylinders, but it was long ago recognized that friction is the highway robber of mechanical energy. Since an early period in the history of the gas engine, when it was necessary to run a new engine with a belt for several days to limber it up sufficiently to keep it moving from one explosion to another with the help of a heavy flywheel, engineers have been seeking a solution of the problem in the development of machines for finishing cylinders more perfectly. Boring machines have been improved greatly in recent years, especially the heavy-duty type for production work, but the lack of uniformity in cast iron, of which engine cylinders are made, that renders it impossible for a boring tool to produce a finish without high and low spots still exists.

Reaming is but a modification of the boring method, and, while claims are made of better results in finish than by boring, the increased pressure on the cylinder-walls by reason of the greater area of cutting members, causes the thin portions of the wall to spring away from the cutters, and when the reamer is withdrawn these thin portions spring back, leaving low places at the reinforced parts of the wall. In the resizing of worn engine-cylinders it is desirable to remove the least possible amount of metal requisite to restore the bore to a round, true, straight and smooth condition. Even if all other requirements could be met successfully with boring or reaming tools, they would have to be set to remove an abnormal amount of metal as compared with other methods, owing to the glazed surface of the cylinder-wall preventing the cutters from taking hold.

Honing is a cylinder-finishing process that has come into extensive use recently. The machine, or tool, consists of a metal frame or cradle supporting three to four abrasive stones that are pressed against the cylinder-walls by springs. The hand-operated type is usually revolved in the cylinder by a portable electric drilling-machine, being moved up and down at the same time, somewhat after the manner of the cylinder lap. A survey of the cylinder-finishing methods employed by 24 well-known builders of automobiles and engines, made early in 1924 by the Research Department of the Society, disclosed that 12 of the number honed the cylinders, 9 finish-ground them and the remaining 3 used the lapping process. In no case was the hone used as a sizing and corrective operation except as a means for removing the tool marks and high spots that remain after reaming, or the slight roughness left after production grinding, and to give a highly-polished surface.

Heavy Cylinder-Grinding Machine Corrects Block Warpage

In any consideration of the boring, reaming and honing methods of sizing and finishing engine cylinders, the difference in the application of these methods in the factory and in the reconditioning shop should not be overlooked. Factory equipment is built for heavy duty

and with special reference to the control of alignment, or squareness of the radial line of the bore with the base of the cylinder-block, which is one of the most vital features in the proper functioning of an automotive engine. No doubt this control is practically 100 per cent successful in factory-finished cylinders, but the unstable nature of cast iron and the adjustment of cooling strains inherent in such an intricately cored casting as a cylinder-block results in radical changes in shape after a few thousand miles of service. These changes invariably manifest themselves in warpage of the cylinder bore out of the vertical with the base of the block, a condition that portable boring, reaming or honing equipment cannot successfully correct.

The standard, heavy-duty cylinder-grinding machine, of which several well-known makes are now on the market, does its work with a small abrasive wheel revolving at high speed on a very rigid arm, or spindle, and cuts away the metal freely without placing undue pressure on the cylinder-wall. The wheel arm is held in a massive eccentric head, which rotates in the same direction as the wheel revolves so that the wheel travels in a true circle, presenting the cutting face to the entire circumference of the cylinder bore in one revolution of the eccentric head. The cylinders to be ground are securely clamped, preferably from the bottom, or crankcase end, whenever this is possible, on heavy plates faced at a perfect right angle to the wheel arm. These plates are carried by a table moving parallel with the wheel arm, thus permitting the wheel to travel back and forth the length of the cylinder bore. The eccentric head, or wheel feed, can be adjusted to remove a practically immeasurable thickness of metal or metal up to 0.005 to 0.006 in. thick with one pass of the wheel in and out of the cylinder. It might be thought that a cylinder refinished by the grinding method would be tapered since the wheel wears down as it grinds. This wear, however, is very slight and the finishing cut is made in and out, so any difference in diameter is scarcely distinguishable with the most delicate measuring instruments.

Such a cylinder-grinding machine is the only equipment used in common by the automobile-engine builder and the reconditioner or rebuilder, and because this machine is capable of restoring the original trueness of the cylinder bore with the base of the block, satisfactorily and economically correcting conditions of cylinder wear with the minimum loss of metal and producing a finished surface equal, if not superior, to that produced by any other known method, regrinding is recommended as the only method to use in reconditioning automotive engine cylinders. The merits of cylinder grinding seem to have been well summed-up in a recent full-page advertisement of a well and favorably known automobile manufacturer, which appeared recently in the New York City newspapers. Under the heading "Ground Cylinders," over the first of "twelve major reasons why this car is not only good, but better," appeared the statement:

> Admittedly superior to reamed or honed cylinders. Make a more perfect seal between piston-rings and cylinder-walls. Eliminate troubles due to imperfect seal, such as oil-pumping, excessive carbon deposit and frequent valve-grinding. They are more expensive to machine but less expensive to operate, because they ensure maximum smoothness, power and efficiency throughout.

Cylinder Grinding Limits and Piston Clearances

Regrinding of the engine cylinders should be done with the utmost care. The condition of each cylinder should be ascertained and the one showing the greatest amount of wear should be ground first. This determines the size to which the other cylinders are to be ground, all of one block, or set of blocks being ground to uniform size within limits of 0.0005 in. plus or minus, with not more than 0.0010 in. total taper. Oversizes for cylinder bores, according to the S.A.E. Standards are 0.010, 0.020, 0.030 and 0.040 in., but few regrinding shops adhere strictly to these figures. The general practice is to grind in variations of 0.005 up to 0.070 in., or even larger, if necessary, when such large oversize pistons can be secured.

Pistons should be fitted with a clearance of 0.00075 to 0.00100 in. per in. of diameter for cast iron, and for alloy pistons the manufacturer's instructions as to clearance should be followed rigidly. Particular attention should be given to roundness of the pistons and squareness of the piston-pin hole with the sides of the piston. Correct reaming of the piston-pin holes to uniform size and proper fit of the piston-pins are of utmost importance. A tight piston-pin will often cause breakage or out-of-roundness of the piston, and a loose one will not give service. Rings should fit accurately in the grooves and, while a rather wide difference of opinion exists as to gap clearance, the best practice seems to call for not less than 0.004 in. per in. of diameter.

If inspection and test of the crankshaft show it to be badly sprung, it should be straightened, then recentered and the flywheel flange trued-up by machining the face. The outside, or rim, of the flange that fits into the seat of the flywheel, must not be touched. Too much emphasis cannot be placed on keeping a crankshaft in perfect condition, and the work of reconditioning a shaft that is worn out of alignment should never be attempted by any of the old methods of filing, turning, lapping or polishing. Satisfactory results can be secured only by the use of machines built especially for crankshaft grinding, of which a number of standard makes are available. The operation of crankshaft grinding is one that requires extreme care. Main bearings should be ground first and the connecting-rod pins then ground parallel with the main bearings. The sides of the thrust bearings and the sides of the connecting-rod pins should be ground smooth; high spots at these points will soon wear down and produce a "sloppy" engine.

Alignment Most Important in Fitting Bearings

With the crankcase mounted in the engine-stand, we now come to the most accurate part of an engine reconditioning job, which is the fitting of the main and connecting-rod bearings. Up to a comparatively recent date, bearings were commonly fitted in one of two ways, by "scraping-in" and "burning-in." The first is entirely a hand operation, consuming much time and producing an effect on the bearing the very opposite of what should be desired, for it lifts the metal up, leaving it porous and soft, instead of dense and hard. In the "burning-in" method the objective is a bearing of maximum density and hardness, but, as this has already been obtained through the modern process of the centrifugal casting of bearings, burnishing of the bearings is unnecessary.

The best engineering practice in fitting bearings today calls for a type of universal equipment for line-boring the bearings, employing a boring bar fitted with fly-cutter tools that can be adjusted to the desired size with micrometer accuracy. Undersize bearings for replacement are now being manufactured for nearly all makes and models of engine, and in cases in which the crankshaft has been reground, new undersize bearings

should always be used. This is particularly important in the case of the main bearings, as fitting a reground crankshaft into the old main bearings changes the timing-gear centers, throwing the timing-gear train "off the track." The pitch line of a set, or train, of gears, which has a direct relation to the rotating center, may be likened to a railroad track, the gears being the cars. So long as they remain on the track, they run with a smooth, rolling, noiseless motion, but once the pitch line is disturbed they become jammed and "growl." The standard tolerance in gears being approximately 1/16 the depth of the tooth, and the teeth of a timing-gear being but 3/16 in. deep, it can readily be seen that a change of but a few thousandths of an inch in the timing-gear centers will have a serious effect on the gear alignment.

Indeed, the success or failure of an engine reconditioning job might well be summed up in the word, "alignment." In fitting the main bearings, they must be kept absolutely parallel with the cylinder base of the crankcase, which may, in fact, be termed the datum line from which all assembly operations are performed. The bearing bores of the crankcase being originally machined parallel with the crankcase base, the point to work from in fitting the main bearings should naturally be these bores.

Operation of Inserting Bearing Halves

Before inserting bearing halves in the crankcase bores, particular care should be taken to see that everything is clean and that no chips or burrs on bearings are allowed to get in between the bore and the outside of the bearing halves, which should be forced into the bores as lightly as possible. It should be borne in mind that the difference between fitting bearings into a new and an old crankcase is a vast one. The bores in a new crankcase are round and true, while in an old one it is difficult to determine what shape they are in. It should also be remembered that the builder of the engine had a manufacturing tolerance in machining the bores of the crankcase and the bearing manufacturer must also have tolerance on the outside diameter of the bearings. For example, if the crankcase bore should happen to be 0.002 in. over standard and the outside diameter of the bearing should be 0.002 in. minus standard, the bearing would then come in contact with the bore only at the very bottom, leaving an opening of 0.002 in. at each side of the bearing at the top. Should the conditions be reversed, that is, the crankcase bore be under standard and the outside diameter of the bearing over standard, the bearing would touch on the sides at the top, leaving an opening at the bottom of the bore. In either case the bearing would soon work loose and give trouble. Not only the manufacturers' tolerances are to be considered, but also the wear and warpage of the crankcase bore, and to compensate for these inaccuracies, it is of the utmost importance that the bearing halves be left 0.002 to 0.003 in. above the crankcase and the cap faces, so that when bolting the cap on the crankcase the faces of the bearing halves will meet before the faces of the cap and the crankcase, thus giving the bearings what is known as a "drive fit," similar to that of a connecting-rod pin-bushing. The fitting of bearings into the crankcase should never be attempted before the block, or blocks, have first been bolted on the case. This brings the crankcase bores into permanent alignment with the cylinder base and, unless the cylinders and the crankcases are thus assembled before fitting the bearings, no assurance of accuracy is possible.

Having properly fitted the bearings into the crankcase, they should be carefully removed, the bearing fixture clamped on the crankcase and the boring tools located from the bores. The bearings can then be replaced in the crankcase and bored to the size of the crankshaft, plus 0.001 in. per in. of diameter for an oil-film. Thrust bearings in the crankcase should next be fitted and as much care should be exercised in securing squareness of the face of the thrusts as in securing accuracy of the diameter of the bearing bore. Before removing the bearing caps after boring and to insure absolute accuracy and uniformity in the resetting of the caps, when putting in the crankshaft, it is recommended that each nut be carefully marked in relation to its stud and that they be brought to exactly the same relation in the final assembly.

The same boring method is used in fitting the connecting-rod bearings. Piston-pins should be fitted in the connecting-rods before the bearings are fitted, and the squareness and twist of the rods checked-up both before and after the boring of the bearings. Sides of the bearings require as much care as the face, as excessive end clearance on the connecting-rod bearing reduces oil pressure and prevents an even distribution of lubricant throughout the engine. Too much clearance will also soon result in a noisy engine, caused by the connecting-rod sliding back and forth on the pins and striking against the sides of the crankshaft and also the piston-pin boss.

Before beginning the work of reassembling the engine, the cylinder-block should again be washed thoroughly to remove all traces of abrasive dust remaining on it from the regrinding operation. The new valve-guide bushings should be pressed in and reamed to fit the valve-stems before the valve-seats in the cylinder-block are refaced. This is an operation that also calls for extreme care, as an out-of-square bushing or valve-stem results in a heavier valve-seat on one side than on the other, causing warpage of the valves.

Perfect Alignment the Secret of Success

Let me repeat that alignment is the secret of success in any automotive engine reconditioning job and that this alignment must be complete with all parts of the engine. Beginning at the cylinder, or crankcase, base, we must have absolute squareness of the cylinder bores with this line and perfect parallelism of the crankshaft with the same line. Connecting-rod pins must be parallel with the main bearings. Connecting-rods must be straight and square and the piston-pins parallel with the crankshaft connecting-rod pins and also square with the sides of the pistons. If there is lack of alignment or of squareness at any of these points, trouble will soon develop and the life of the engine will be appreciably shortened. It is useless to attempt to compensate at one point for error at another. For example, if the connecting-rod pins on the crankshaft are not parallel with the main bearings, the squareness of the connecting-rods is useless because the connecting-rod pins on the crankshaft will throw them out of square. If the connecting-rod is squared with the crankcase or the cylinder bore, the parallelism of the piston-pin and the connecting-rod bearings is thrown out. All of these points must be given the very closest attention if trouble is to be avoided.

The time available for presentation of this paper limits the discussion of the fitting of timing-gears, camshafts, idler gears, idler-gear bushings, water-pump and magneto shafts, and the putting into mechanical order of valve

push-rods and adjusting screws. Suffice it to say that these operations require as great precision as has been indicated in those that have been described. Always remember that it is false economy to try to make worn parts do when these parts are of such a character and size that they cannot be refinished economically. New parts cost much less than the labor necessary to make most of the smaller parts serviceable, and no matter how much labor is put on them they will not give the service that may be expected from new parts.

The minor points in engine reconditioning, such as final assembling, replacing in the frame and tuning up, may also be passed over without discussion. If the major operations of reconditioning are performed as has been described, the result will be an engine in every detail equal, if not superior, to a new one.

APPLYING JIGS AND FIXTURES TO ENGINE-BLOCK MACHINING

(*Concluded from p. 324*)

bushing. The bushings are generally the first part of the jig to need replacing, and those of a standard interchangeable-liner type are easily obtained and easily replaced. Usually, to replace a drive-fit bushing, the entire jig must be removed from the machine, taken to the toolroom, be at least partly dismantled, and have a new bushing made to fit the hole. But a removable-liner bushing, kept in stock in standard sizes, requires only that the machine be stopped for the maximum of 2 or 3 min. while the old bushing is lifted out and a new one slipped in without the aid of a single tool. The loss of time to the machine is therefore but a matter of a few minutes, as compared with perhaps half a day.

By using duplicate clamping-parts, such as handles, knobs, screws and the like on as many jigs as possible, not only will much time be saved in the drafting room but a smaller stock of replacement parts will be needed.

General Design

In the general design of a fixture, the considerations of strength and rigidity must be kept in mind at all times. There is seldom any object in holding down weight; the addition of 100 lb. of metal will cost but a few dollars and may save several hundred dollars' worth of trouble later. The base, or jig body, should be of heavy section, well ribbed, and made as nearly as possible like a surface-plate. This will leave little possibility of warping and the consequent throwing out of line of the locating points or bushings. Bushing plates should be designed with deep enough section or ribbing to prevent warping and should have plenty of supporting length for the bushings. They should be attached so that no possible chance exists of their moving out of alignment. Sufficient chip-clearance should be provided between the fixture and the work.

It is also important that all locating surfaces be self-cleaning. This must be accomplished in a variety of ways to suit the conditions but, in general, surfaces can be sloped away from horizontal locating-points as shown in Fig. 5, so that chips will roll away. Vertical locating-surfaces usually can be placed high enough above any horizontal surfaces so that chips will not accumulate in front of them. Wherever possible, openings should be provided in the wall of the fixture below these surfaces to allow chips to fall out.

Results of Cooperation

As an example of the extent to which cooperation between the engineering and the tool-engineering department can be carried, the matter of boring cam and crankshaft holes in the Cleveland six-cylinder engine-block is cited. This is a three-bearing job and, at the tool engineer's suggestion, the cam and the crankshaft bores were designed in steps; that is, starting at the front, each successive bore is stepped up to a slightly larger diameter and, with this design, a much more efficient method of boring is made possible. As shown in Fig. 6, the work is done on a double-end machine having Kelly-type bars, two of which are long enough to reach the center cam and crankshaft bearings. In the ends of these bars are sockets to take the shank of a core drill of the same diameter as that of the rough bore of the center bearing. The successive cuts are as follows: The core drill first cuts out the rear bore and is followed by a fly-cutter that rough-bores it to a larger diameter as the core-drill cuts the center hole. Meanwhile, a similar core-drill cuts the front hole to its rough-bore diameter from the opposite end. Removal of cutters from the bar between bores is eliminated in this way. The fixture supports the bars in bushings, one outside of each end-hole and one just back of the center. The bushing at the rear end is fitted with an inner bushing that is keyed to the bar and rotates with it. It is slotted for the passage of the Kelly cutter. It is estimated that this method represents a saving of time of about 50 per cent when compared with the usual way, in which all bores are of the same diameter and the cutters must be removed from the bar and inserted again between the bores. The finish boring is then done on a single-end machine with removable bars and fixed cutters. The feed is reversed in this case, the bars being pulled toward the head instead of being pushed from it.

Recent Diesel-Engine Developments

By Philip L. Scott[1]

Chicago Section Paper *Illustrated with* Drawings and Photographs

ABSTRACT

WHAT the Diesel engine has done, its possibilities of development and future application to automotive service, are major topics of the paper. When modified for automotive usage, the author asserts that the Diesel engine would not only allow the use of cheaper fuel and provide greater fuel economy, but it would give immediate opportunity to use the two-stroke cycle; that is, it would generate about twice the power for an equal weight of mechanism, compared with present power attainment. In addition, the two-stroke cycle makes possible partial or entire elimination of exhaust-valves, exhaust through ports being better in every respect, and the Diesel-engine principle affords the possibility of a two-stroke-cycle double-acting engine in which, theoretically, four times the power of the present gasoline engine would be available.

Fuel injection provides other advantages, such as the elimination of crankcase-oil dilution and the fact that no fuel is present in the cylinder until the instant of combustion, just enough fuel then being fed continuously to keep the fire going. But the author says that we must consider injection engines as being slightly more expensive than carbureting engines at present, and that it is the possible ultimate use of the two-stroke-cycle engine which would make it less expensive.

The growth of the Diesel engine in size is traced, some of its history and some applications being described in conjunction with illustrations. The status of large Diesel engines is outlined in like manner, the heat flow in these large units is explained and high-speed injection-engines are analyzed, since they already have broken into the automotive field for use on motor rail-cars and small locomotives.

In this Country, three classes of railroad service exist to which the Diesel engine is applicable: Self-contained rail-car units of up to 100 hp. having from 40 to 80-passenger capacity, a "short-haul" unit of about 300 hp. capacity and a large locomotive of 1000 hp. or greater capacity for freight and passenger service to haul standard car-equipment. Diesel engines have been built for the last two classes but, for the present, the first class has been left to the gasoline engine.

Research is being conducted to fit the Diesel type of engine to the power demands of the automobile, the motor truck, the tractor and the airplane. After describing special types of engine that utilize the Diesel principle, the author states that the paper aims to present the position the Diesel engine is likely to occupy as a prime-mover within the next few years.

ESTABLISHMENT, commercially, of the automotive type of Diesel engine in Europe leads us to inquire what advantages the Diesel engine, more properly called the "injection engine," has when modified for automotive use and what it means to automotive service. It means not only better fuel economy and cheaper fuel but, the immediate opportunity to use the two-stroke cycle or, at once, to secure about twice the power for the same weight and mechanism. The two-stroke cycle also makes possible the elimination or, partial elimination, of valves, exhausting through ports being better in every respect than exhausting through valves. It goes beyond this for some purposes, in that

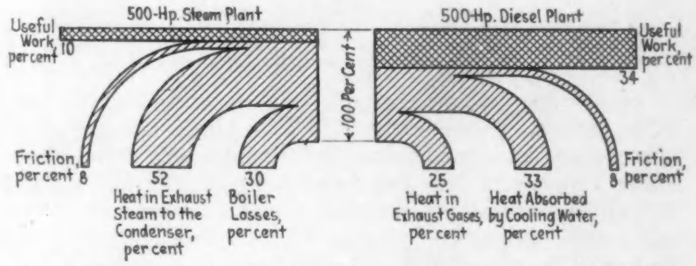


Fig. 1—Steam-Engine Versus Diesel-Engine Utilization of Heat
The Chart Shows How the Energy in the Fuel Is Distributed in a 500-Hp. Powerplant, Affording a Comparison between the Performances of a Steam and of a Diesel Engine as Prime Movers

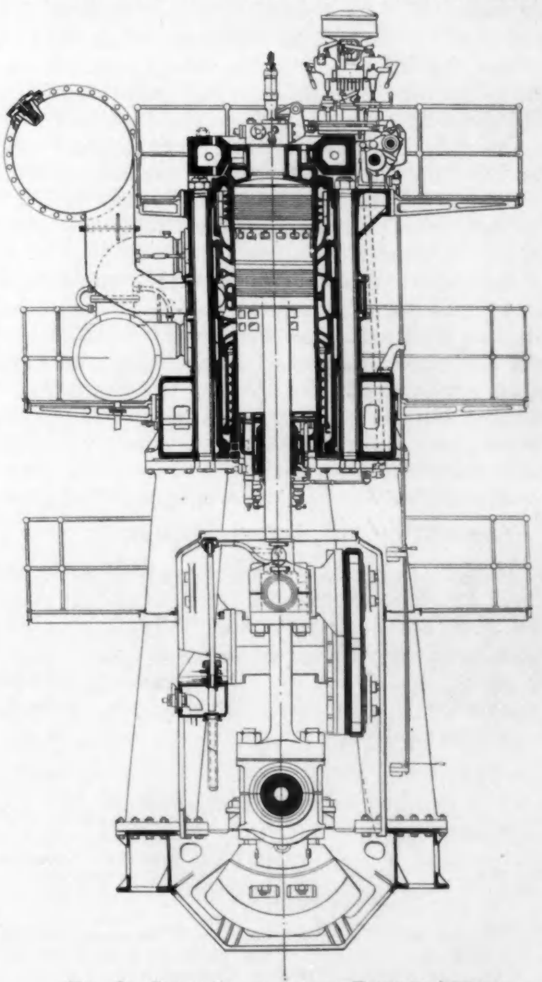


Fig. 2—Cross-Section of a Double-Acting Two-Stroke-Cycle Engine
The View Illustrates the Arrangement of the Valveless Scavenging Ports

[1] M.S.A.E.—Consulting engineer in charge of development work, Super Diesel Tractor Corporation, LaPorte, Ind.

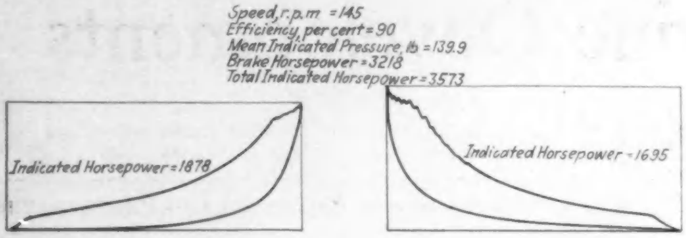


FIG. 3—INDICATOR-CARDS FROM A NURNBERG DIESEL ENGINE
This Was a Six-Cylinder Double-Acting Two-Stroke-Cycle Engine That Finally Developed 17,000 Hp. The Peculiar Combustion Line and, Particularly the Very Sharp and Distinct "Cut-Off" of the Fuel As Shown by the Expansion Line, Should Be Noted

it makes the two-stroke-cycle double-acting engine possible, which, theoretically, has four times the power of the present gasoline engine, but actually only about three times because of loss due to piston-rod area and an unfavorable combustion-chamber on the lower side. The additional advantage of the higher thermal efficiency may also be considered.

The injection engine has suffered somewhat through being called a "heavy-oil engine," while, apparently, we are not yet at the end of our gasoline resources, and the injection engine can burn gasoline. The average power of the fuel which reaches the road from a four-cycle automobile engine is about 6 per cent. An injection engine, if it runs at all, will deliver at least 15 per cent of its fuel power on the road and should give at least 20 per cent under similar use. Assume roughly an efficiency ratio of 3 to 1; and a ratio of 3 to 1 for the present cost of fuel oil as compared with that of gasoline; then the injection engine would cost but one-ninth to run as compared with the four-cycle gasoline engine. This is the extreme case and, as the load factor becomes more favorable to the gasoline engine, this advantage to the injection engine decreases to become a ratio of about 4 to 1. This condition is inherent in the engine and is not based on some remarkable construction or marvelous invention.

Another point of importance with regard to the injection of fuel into the Diesel engine is that crankcase-oil dilution elimination is inherent. No fuel is in the cylinder until the instant of combustion and then, just enough is continuously fed to keep the fire going during the stroke; but, for the present, we must consider injection engines as slightly more expensive than carbureting engines. The ultimate use of the two-stroke cycle will reverse this disadvantage in initial cost.

GROWTH OF THE DIESEL ENGINE IN SIZE

The Diesel engine is taking its place with amazing rapidity. Dr. Diesel built his first engine 32 years ago, and the first Diesel engine was built in this Country 15 years ago; now, engines big enough to drive the largest ships are available. In steam-engine development nearly 90 years elapsed between the Clermont and the large steam-turbine ocean liners; now, 34 per cent of all the world's shipping on the shipways is to be Diesel powered, according to Lloyds' Register.

FIG. 4—TYPICAL INDICATOR-CARDS FROM 30-DAY TEST OF A WORTHINGTON ENGINE
This Was a One-Cylinder, 27 x 40-In., Double-Acting Two-Stroke-Cycle Diesel-Engine. The Engine Ran at a Steady Average Speed of 89.8 R.P.M. without a Stop during the Entire 30-Day Test and the Exhaust, Observed Close to the Outlet from the Cylinder, Was at All Times Invisible

As to full use of the mechanical linkage involved in the energy transformations, the Diesel engine is now on a parity with the steam engine and it is three times as efficient thermally. The record on land and sea shows that a carefully chosen and properly attended Diesel powerplant is fully as reliable as steam. The much higher efficiency of the Diesel engine compared with that of the steam engine involves higher heat and mechanical stresses; therefore, it demands greater operating intelligence than does the steam engine, just as the automobile driver must use more intelligence than the horse driver; although it is to be regretted that this factor of performance is often low. What has to be paid in this way is far less than the gain in thermal efficiency. Many unsuccessful Diesel installations are due to selecting an engine unsuited to the job and to failure to maintain it properly.

FIG. 5—DIESEL-ELECTRIC LOCOMOTIVE
The Engine Runs at 600 R.P.M. and Develops 300 B.Hp. It Has Six Cylinders of 10-In. Bore and 12-In Stroke, Operates on the Price Solid-Injection System and Shows a Fuel Consumption of 0.43 Lb. per B.Hp-Hr. The Locomotive Weighs 60 Tons and Is Hauling an Eight-Car Train

Fig. 1 shows where the energy in the fuel goes, as heat, in a steam and in an oil prime-mover for a 500-hp. plant. Beyond the physical laws involved, this may well be credited to the good engineering precept that simplicity is excellence. The Diesel engine is the only truly self-contained prime-mover unless, perhaps, we drive automobiles with windmills.

As a background from which to view the newest field in which the Diesel engine is developing, let me present the impressive engines of very large powers now in use and building. The largest is a 15,000-hp. stationary unit of the Maschinenfabrik Augsburg-Nurnberg. The engine has nine cylinders, a two-stroke cycle and is double acting; it is 67 ft. 6 in. long, 13 ft. 6 in. wide and 26 ft. 11 in. high. It is truly a Goliath. Blohm & Voss are building a similar engine. The costs are estimated at $60 per hp. and the weight is less than 200 lb. per hp. The Nelseco Company is reported to be building a double-acting two-stroke-cycle engine from Maschinenfabrik Augsburg-Nurnberg designs, a cross-section being shown in Fig. 2. A "four-story" engine longer than an average house furnishes good food for thought. The energy it releases is controlled by one man.

Before this, during the war, the Maschinenfabrik

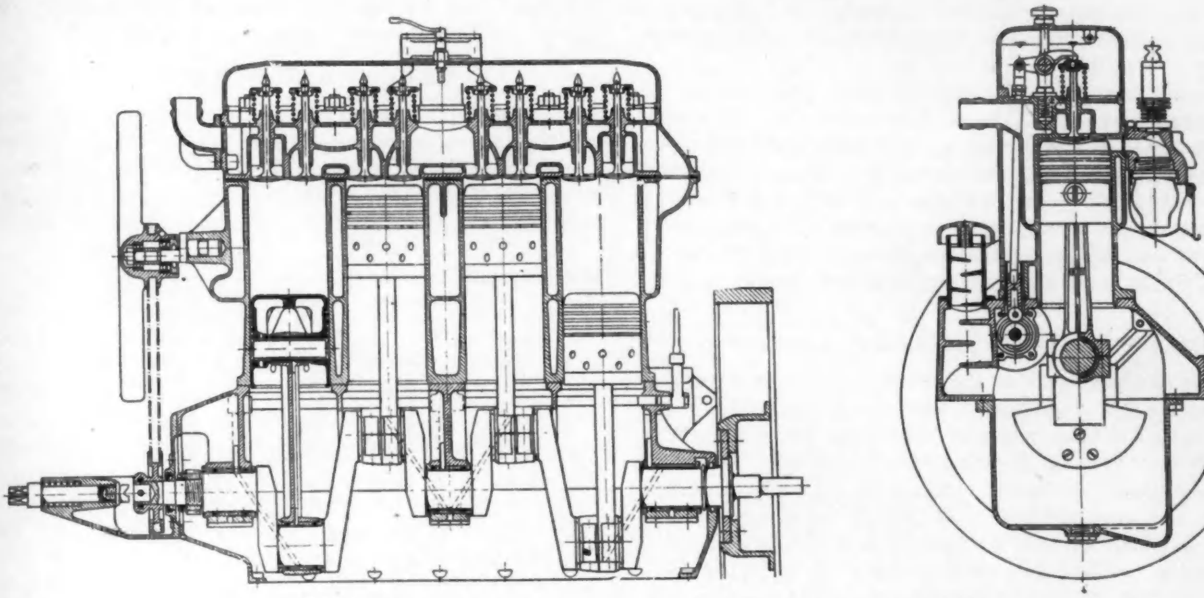


FIG. 6—BAGNULO SURFACE-IGNITION ENGINE FOR AUTOMOTIVE PURPOSES
The Fuel Is Injected into a Glowing Bulb or Incandescent Chamber Shown in the View at the Right

Augsburg-Nurnberg built first a single-cylinder test-unit and finally a six-cylinder double-acting two-stroke-cycle engine that eventually developed 17,000 hp., maximum; it has a scavenging compressor at one end. The weight of this engine was 112.5 lb. per b.hp., which is an amazingly small weight for low rotative speeds; the fuel consumption was 0.42 lb. per b.hp-hr.; and the maximum piston speed was 1458 ft. per min. Fig. 3 shows indicator-cards from this engine. The peculiar combustion line and, particularly, the very sharp and distinct "cut-off" of the fuel as shown by the expansion line should be noted. This engine was destroyed under the Versailles Treaty.

The famous Krupp organization has also built a 12,000-hp. two-stroke-cycle, double-acting battleship engine; it has a 34.45-in. bore, a 41.34-in. stroke and a speed of 108 r.p.m. The motor liner Gripsholm, recently launched, has 20,650 hp. of Diesel engines for her total plant. The main engines are double acting but are four-stroke cycle; each develops 8150 i.hp. and 6750 b.hp. The bore is 33.07 in., the stroke is 59.05 in. and the speed is 125 r.p.m.

American Diesel-engine construction is on a very different basis from that current in Europe. Economic pressure in Europe has fostered the development of the most efficient prime-mover, and technical and labor costs are much lower. Our huge natural wealth has not compelled us to be very economical as yet, although we are beginning to feel the need. Labor and design costs here are much higher. We have, truly, the advantage of

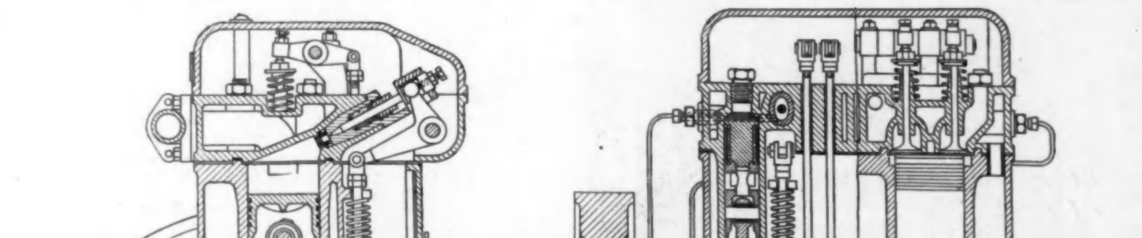


FIG. 7—HINDLMEIER HIGH-SPEED DIESEL-ENGINE
A Portion of the Air Is Compressed to a Pressure of 700 Lb. per Sq. In. and This Blazing Hot Air Is Blown past the Spray Just at the Moment That Injection of the Fuel Begins, Causing Ignition and Continuation of Burning in the Main Cylinder; the Remainder of the Air Has a Maximum Pressure of about 400 Lb. per Sq. In. The Engine Speed is 1150 R.P.M.

much better mass-production methods, but the large Diesel engines do not lend themselves to mass production.

In considering this general situation, one unique exception and phase of Diesel development exists here. Fairbanks, Morse & Co. can be considered in mass production on engines up to 360 hp., for it is building 3000 hp. per week steadily in its shops. McIntosh & Seymour is building a double-acting four-stroke-cycle engine of 32-in. bore and 52-in. stroke to develop 2700 hp. at 95 r.p.m.; its single-acting engines are well known in this Country.

Heat-Flow in Large-Engine Designs

In large engines, one of the most important problems is the very high heat-flow. For comparison, take the 8-in. airplane-cylinder recently developed and compare it with a 32-in. two-cycle double-acting cylinder. The ratio of volume to wall surface is then 1 to 2 in the first and 1 to 8 in the second case; four times as much heat is liberated per unit of wall surface if both are four-stroke-cycle engines. This increase is then 1 to 8 for two-stroke cycle but, because the volumetric-combustion efficiency is about 60 per cent in the case of the Diesel as against that of the airplane cylinder, the actual heat liberation is only about five times greater. With flame both above and below the piston and in both ends of the cylinder, a further heat strain is set-up.

The cooling of an 8-in. aircraft-engine cylinder is not easy. This means that, in Diesel design, the utmost care must be taken to allow for expansion of all parts subjected to heat, and that sections must be as uniform and as simple as possible and cooling as thorough as possible. The Worthington organization has attacked this problem by making both cylinder-heads as steel forgings of uniform and thin section. The cast-iron barrel is very thin and is held in a steel jacket having labyrinth passages for rapid cooling-water circulation. Fig. 4 shows indicator-cards from this engine.

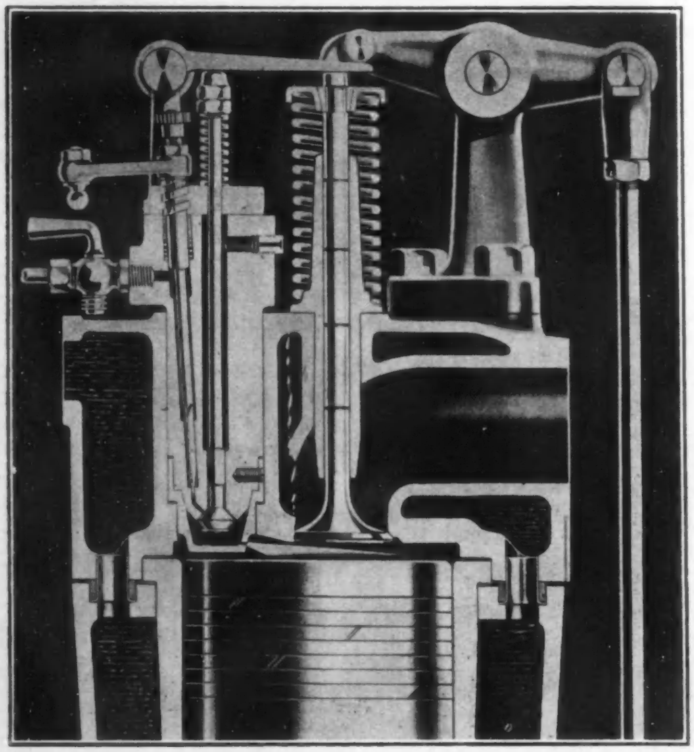


Fig. 8—The Hvid Engine
The Fuel Is Fed into a Cup, by Suction, Together with a Little Air. A Small Hole in the Cup Communicates with the Main Cylinder and the Cup Is Fairly Hot. The Vapors in the Cup Explode as the Compression Reaches Maximum, Blowing-Out the Remainder of the Fuel for Final Consumption in the Main Cylinder

High-Speed Injection-Engines

The Diesel engine, in addition to developing into very high powers, is also establishing itself in higher and higher speeds. The Diesel locomotive has been an established fact for some time in Sweden, Denmark, Switzerland and Germany and is now established in Russia. In this respect it has broken into the automotive field in high-speed light-weight engines for rail-cars and small locomotives. The Soviet Government has purchased a 1200-hp. locomotive recently.

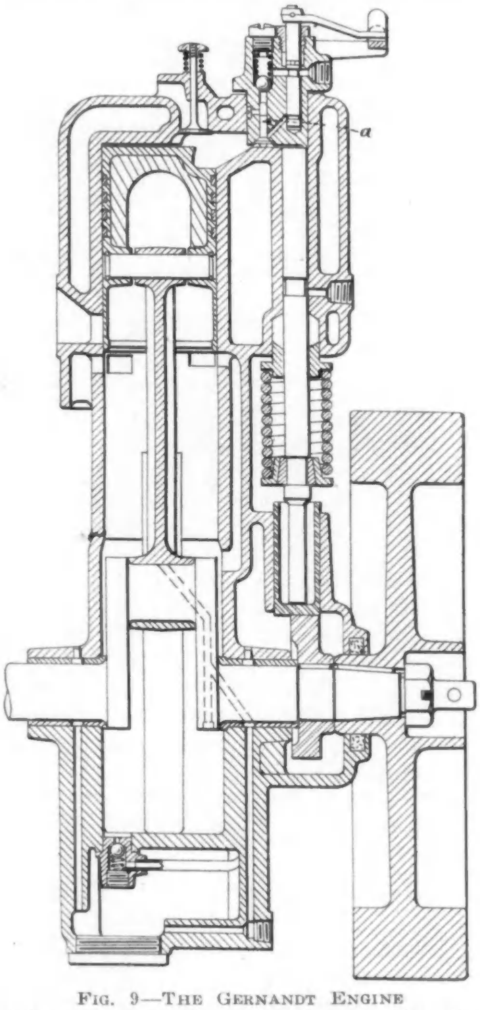


Fig. 9—The Gernandt Engine
It Has Gas Injection of the Fuel, Avoiding the Difficulties Encountered in Compressing and Using Air Immediately for This Purpose. The Exhaust Gas Is Compressed by the Small Compressor Shown and This Blows the Fuel, Which Previously Has Been Fed past the Check Valve at *a* and into a Small Pocket, Out into the Cylinder, without Burning in the Small Passages and Narrow Slit for Atomizing

A recent Danish development is a Diesel electric car and trailer, with a 90-hp. Holeby-engine. The car will accommodate 52 people. The fuel cost in operation is one-fifth that of coal under the same conditions. Sulzer Freres in Switzerland has built a 200-hp. Diesel electric rail-car with trailer, having a total passenger accommodation for 85 people. The cost of its operation is about 0.03 cent per ton-mile.

The Swiss Locomotive & Machine Works produced an 80-hp. solid-injection engine having a 9-in. bore and an 11.4-in. stroke. This engine is for switching service and is direct connected through change-speed gears to

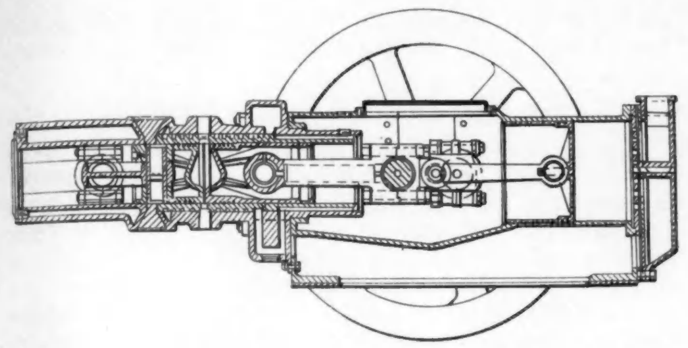


Fig. 10—Experimental Tractor Engine
It Is an Oil-Burning Engine Having Double-Piston Construction and Utilizes the Principle of Fuel Injection

the driving wheels. A system of clutches is used in changing gears, which are constantly in mesh.

One of the most striking developments is the Maybach engine, a part of the Zeppelin undertakings. This engine is also direct connected through gears and clutches to the driving wheels. Especial interest attaches to it because of its speed of 1300 r.p.m. and its weight of 18 lb. per b.hp. A gasoline engine for similar service would weigh about 15 lb. per b.hp. Without question the Diesel engine has entered the automotive field commercially.

We have been busy on the problem in this Country also, and the classes of railroad service seem to be three. First, a self-contained unit for from 40 to 80 passengers for suburban runs, having up to 100 hp. Second, a separate Diesel engined locomotive of about 300 hp. to handle the short haul traffic. This field is pressing now as in many cases it is being operated at a loss. Mail, freight and express must be hauled even in sparsely populated localities. A moderate-powered Diesel-locomotive capable of handling standard equipment would put this business on a paying basis. Third, the large locomotive of 1000 hp., and more, for freight and passenger service, hauling standard car-equipment. In the second and third classes, engines have been built; but the first class has been left to the gasoline engine for the present. Abroad, the small high-speed service has been attacked first.

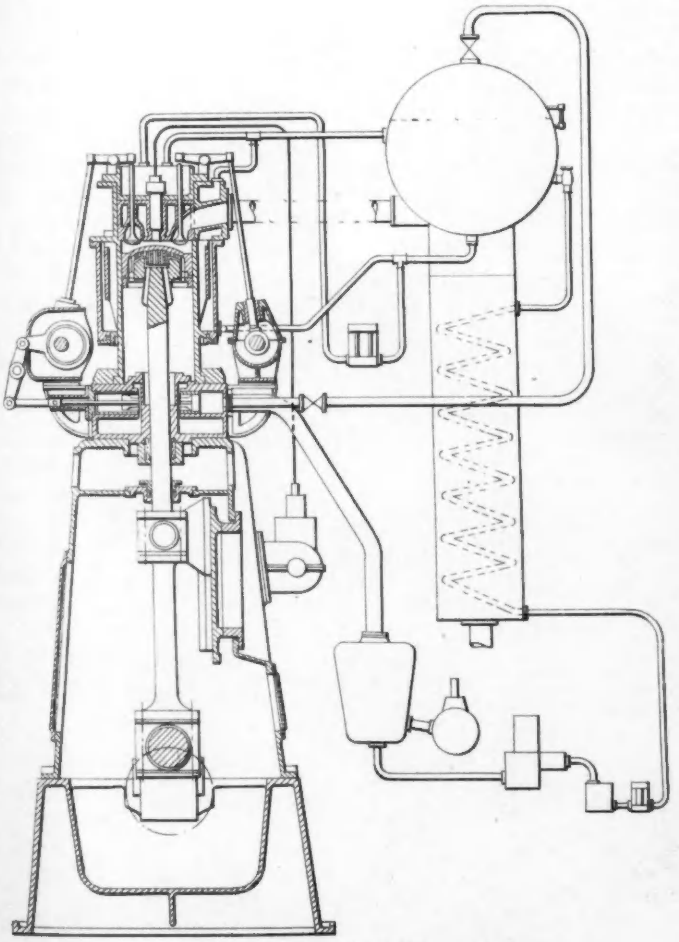


Fig. 11—The Still Engine
This Is a Combined Oil-Burning and Steam Engine. The Upper Side of the Piston Is a Diesel "End" of the Usual Layout. The Exhaust Gases of this "End" Are Used, Sometimes with Auxiliary Heat, To Raise Steam To Act on the Under Side of the Same Piston. The Engine Is Started by Steam Raised in the Boiler by Auxiliary Heat, Instead of Using Compressed Air

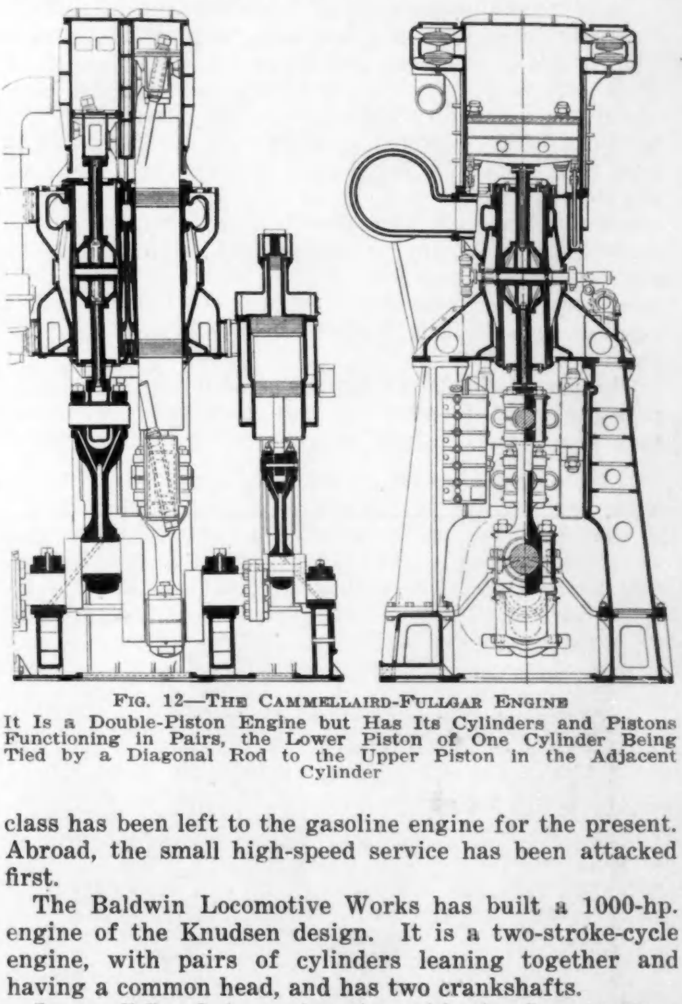


Fig. 12—The Cammellaird-Fullgar Engine
It Is a Double-Piston Engine but Has Its Cylinders and Pistons Functioning in Pairs, the Lower Piston of One Cylinder Being Tied by a Diagonal Rod to the Upper Piston in the Adjacent Cylinder

The Baldwin Locomotive Works has built a 1000-hp. engine of the Knudsen design. It is a two-stroke-cycle engine, with pairs of cylinders leaning together and having a common head, and has two crankshafts.

Ingersoll-Rand, in conjunction with the General Electric Co. and the American Locomotive Works, has built and had in use for some time in various kinds of service a 300-b.hp. Diesel-electric locomotive, shown in Fig. 5. The engine runs at 600 r.p.m., operates on the Price solid-injection system, and the fuel consumption is 0.43 lb. per b.hp-hr.; it has six cylinders of 10-in. bore and 12-in. stroke. This engine has an interesting fuel-pump having but a single plunger to supply the six four-cycle cylinders. The plunger makes 1800 strokes per min. and delivers oil to the proper cylinder through an intermittently rotating disc distributor. The reason for the intermittent motion of the disc is that the bearing pressure on a continuously rotating disc delivering oil under say 3000 lb. per sq. in. pressure is a problem if the undesirable stuffing-box is to be avoided.

In the foregoing construction, the disc jumps during the suction stroke of the plungers when there is no pressure on it. When the pump starts its delivery stroke and the pressure comes, it helps to make a good seal. The speed of this pump controverts an idea that has been

voiced frequently, that oil cannot be metered accurately and delivered under the high pressures necessary at speeds high enough for automotive work. In my own experience, we have delivered oil at 15,000 lb. per sq. in. at the rate of 1200 r.p.m. and with the full-load charge of but 0.003 cu. in., and have metered it accurately from that on down to just enough to keep the engine idling. As a matter of fact, although the engine speed was 1200 r.p.m., the actual time in which delivery took place to the fuel atomizer was but one-tenth of a revolution or at the rate of 12,000 times per min.

In a recent exhibition of locomotives at Seddin, in Germany, 8 of the 40 locomotives were Diesel powered and, in addition, 14 gas and Diesel rail-cars were shown. It is safe to say that we and our goods will be hauled about the country on rails by the far more economical, smokeless Diesel engine to a considerable extent in the next few years. No firing-up is required with the Diesel engine; just move a lever or two and it is ready for service. However, the Diesel locomotive costs much more than the steam locomotive, and although this cost can be reduced, probably it always will be considerably more expensive than steam on first cost; but it will be possible to write this burden off in relatively short service.

The use of the Diesel as compared with electrification presents good possibilities. It must be remembered that the Diesel is fully as economical in the smallest units, as are the largest central steam-electric plants. Both smoke and possible third-rail danger are eliminated.

Automotive Diesel-Engine Development

Having given a survey of the growth of the Diesel in very large powers, that make it available for the largest ships and the big central power-stations and in the direction of higher speeds and lighter weights actually entering the automotive field, it seems proper to go beyond these commercial accomplishments and describe research that is going on to fit this type of engine for the enormous horsepower demands of the automobile, truck, tractor and airplane.

The National Advisory Committee for Aeronautics has been working at Langley Field, Va., with a Liberty-aircraft-engine cylinder set-up having a fuel pump and an atomizer and operated at full speed on fuel oils; at first with a power rating lower than standard but, finally, when changed over to two-stroke cycle, at a rating about 75 per cent above standard. In the first part of the experiments the normal cylinder-head was used and the piston was lengthened to project into the combustion-chamber to give a compression ratio of 11 to 1. The resulting shape of combustion-chamber failed to meet one essential of direct injection, namely, the spray and the combustion-space did not fit each other. Too much air was trapped out of reach of the spray. This was

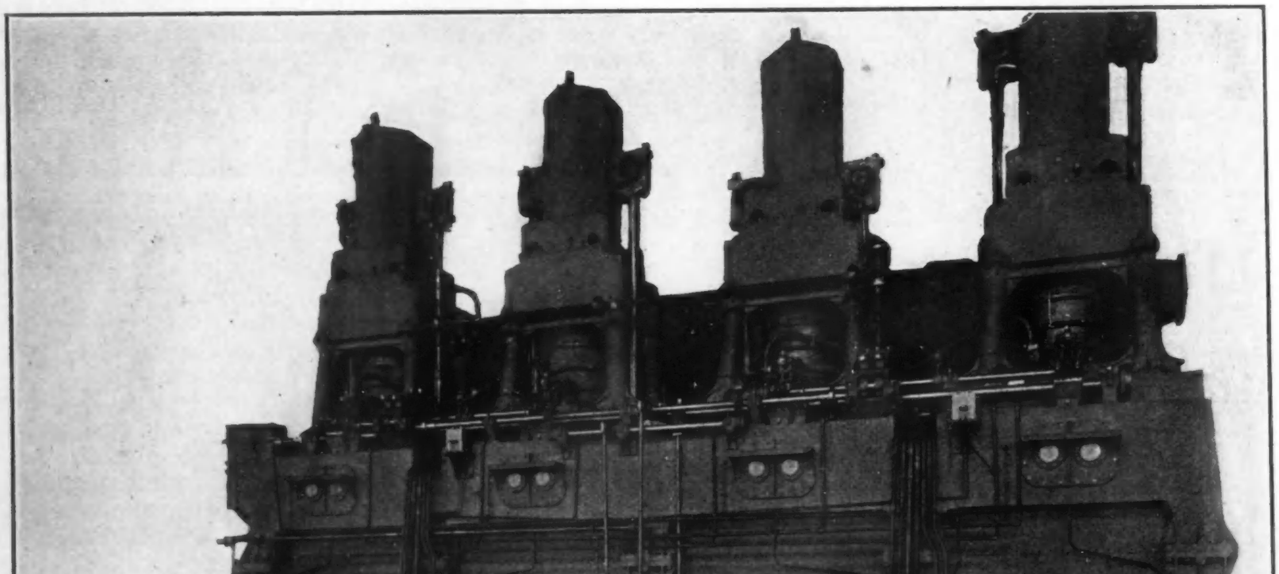


Fig. 13—The Sun-Doxford Engine
Based on the Junkers Double-Piston Construction. This Engine Is Remarkable for Its Light Weight of 217 Lb. per Hp. at the Extremely Low Speed of 77 R.P.M.

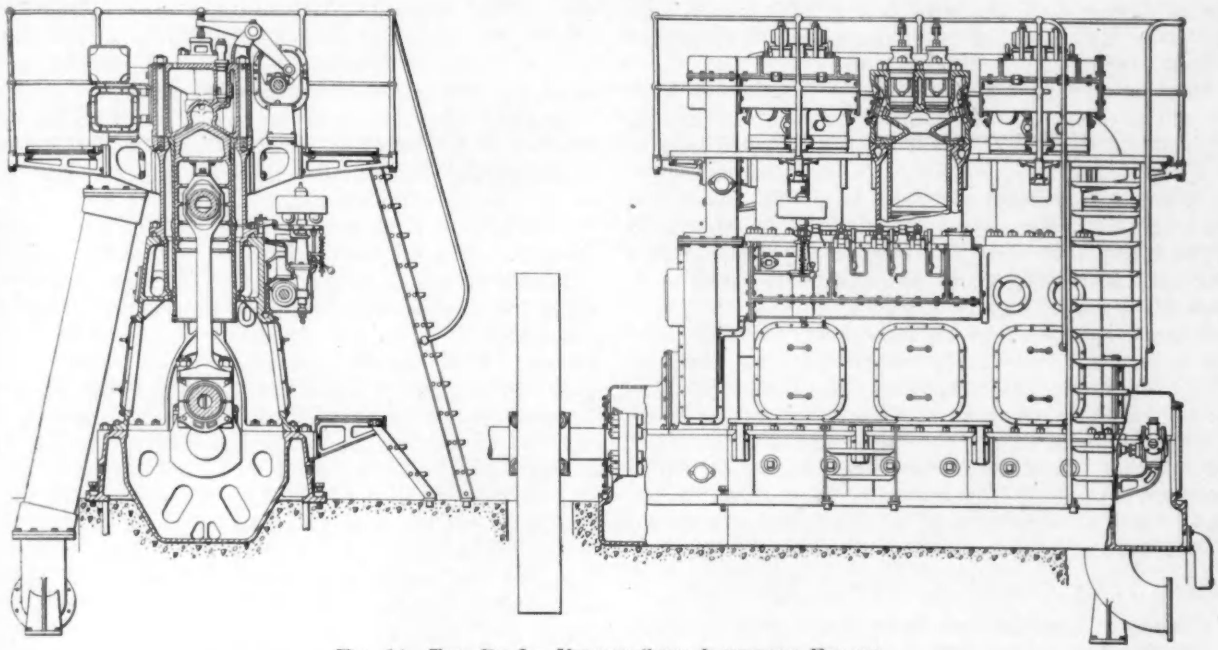


FIG. 14—THE DE LA VERGNE SOLID-INJECTION ENGINE
It Uses the Opposed Sprays and the Separate Combustion of the Price System. Compression Is to 350 Lb. per Sq. In. and the Burning Pressure Is 500 Lb. per Sq. In.

later corrected by a redesign of the head and the piston so that the spray "fitted" better.

In injecting fuel at such speeds as 1750 r.p.m., it must be remembered that only about 0.003 sec. is available, in which to reach all the air in the chamber with the minute fuel-particles. In the large engines spoken of in the first paragraphs, about 0.070 sec. is available for this purpose. In comparison, one might almost crawl inside the cylinder and light the stuff with a match.

A variable-compression engine will soon be available for injection experimentation. The compression can be varied while the engine is running and also the timing of both valves and of the injection.

Fig. 6 shows the Bagnulo development in which the fuel is injected into a glowing bulb. This work is being carried on by the German General Electric Co. The Benz Company has been active in the production of an automobile. In this engine the fuel is fed by a distributor under light pressure into a separate chamber that is partially uncooled and that has communication with the main cylinder through a small hole. Compression finally causes partial combustion in this chamber and the remainder of the fuel is blown out through the small hole, to be completely burned.

Elmer A. Sperry writes that one of his unusual compound engines of 6 to 1 ratio and weighing but 11 lb. per hp. has recently passed Naval acceptance tests.

Peugeot, in France, has been working for some time on the Tartrais system that comprises a very hot combustion-chamber shaped as a toroidal ring and hollow inside. The fuel valve extends axially through one side of this hollow "doughnut," through the "hole," that being also the axis of the cylinder. Compression forces air through the other side of the hole, which is open to the cylinder; the air takes a vortical motion, with the purpose of cutting across the flat spray thrown from the valve at right angles to its axis, and produces a very thorough mixture. Some motorbuses actually have been run on the streets of Paris, but no definite information is available. Fiat, in Italy, is reported to have exhibited a tractor powered with an injection engine, but I have not been able to get satisfactory information about it.

Hindlmeier, in Austria, has turned out an interesting high-speed engine in which but a portion of the air is highly compressed to 700 lb. per sq. in. This blazing hot air is blown past the spray just at the moment that injection of the fuel begins, causing ignition and continuation of burning in the main cylinder during the stroke, with the remainder of the air at about 400 lb. per sq. in. maximum pressure. Fig. 7 gives two sections of this design. The thought of a single-stage compressor for 700 lb. per sq. in. pressure for each engine cylinder is surprising, but it is reported that the engine is in production for small stationary types; its speed is 1150 r.p.m.

In this Country, several companies are working on the automotive Diesel, or injection engine. Some material is available for publication, but much more is not available yet.

The Hvid engine shown in Fig. 8 is probably known to most automotive engineers. It has been run experimentally to 1800 r.p.m. The fuel is fed into a cup, by suction, together with a little air. A small hole in the cup communicates with the main cylinder, and the cup is fairly hot. The vapors in the cup explode as the compression reaches the maximum, blowing out the remainder of the fuel for final combustion in the main cylinder.

The Gernandt engine is shown in Fig. 9. It is interesting in that it has gas injection of fuel, avoiding the difficulties encountered in compressing and immediately using air for this purpose. The exhaust gas is compressed by the small ringless compressor shown and this blows the fuel that previously has been fed past the check valve *a* and into a small pocket, out into the cylinder, without burning in the small passages and narrow slit used for atomizing.

The work with which I have been connected is based partly on development by Prof. Hugo Junkers, in Germany. I was fortunate enough to be able to inspect his double-piston airplane-engine 10 years ago. It has been reported that a few of these engines actually were in

use toward the end of the war, but I have never been able to verify it. Nothing has been done since because of the treaty restrictions.

Fig. 10 shows an experimental tractor engine we have worked with, also of the double-piston construction. Recently, we have converted a commercial-truck engine to injection of fuel rather than carburetion and without high-tension ignition, although a 6-volt hot-coil is used for starting. However, this work is fairly recent and, beyond the fact that the engine runs and starts easily by hand and pulls about two-thirds its rated load, no satisfactory report can be made.

It is often forgotten that an American, Brayton, was the first to use the constant-pressure cycle in internal-combustion engines. He antedates Dr. Diesel by several years. In this engine, however, the air is compressed outside the working cylinder and is fed into the working cylinder along with the fuel. Indicator cards very closely resembling steam-engine cards can be obtained and work on this system is being undertaken by John H. Barnard.

Special Types Embodying Diesel Principles

The preceding descriptions have dealt largely with rather conventional construction as regards the mechanical linkages. The Diesel engine has the distinction of having suggested a number of unusual mechanical arrangements that have met with decided commercial success. Although most of this practice is not recent, yet it seems proper before closing to give a brief description of these forms and to say a word about the design that is in "mass-production," as already referred to.

The Still engine, an English production, is a combined oil and steam engine. Fig. 11 shows the construction diagrammatically. The upper side of the piston is a Diesel "end" of usual layout. The exhaust gases from this "end" are used, sometimes with auxiliary heat, to raise steam to act on the under side of the same piston. The highest thermal efficiency of that of any engine has been claimed for this design because of the saving of some of the heat in the exhaust gases. The engine is started by steam raised in the boiler by auxiliary heat, instead of using compressed air, as is common. Some of these engines are in service and have given a good account of themselves.

The Cammellaird-Fullgar engine shown in Fig. 12 is a double-piston engine but has its cylinders and pistons functioning only in pairs, as the lower piston of one cylinder is tied by a diagonal rod to the upper piston in the adjacent cylinder. It has a most unusual "cylinder" for providing the scavenging air. This air pump is rectangular in cross-section and will be noted on top of the upper pistons. However, it seems to work well. A number of these engines are also in satisfactory service.

The North British Company has produced an unique double-acting engine in which no stuffing-box is used. The 2000-hp. three-cylinder engine operates at 100 r.p.m. on two-stroke cycle and is of 24½-in. bore and 44-in. stroke. The peculiarity of the construction lies in a long double-headed piston having a piston-pin and the connecting-rods straddling the cylinder, and with a cylinder that moves a slight distance up and down to open and close the ports.

The Sun-Doxford design in Fig. 13 is based on the Junkers double-piston construction. This engine is remarkable for its light weight, 217 lb. per hp., at the extremely low speed of 77 r.p.m. The engine develops 3000 hp. Two, recently placed in ore carriers of the Ford Motor Co., have given excellent records so far and others are on order. Several are in ocean service and have long records of trouble-free performance. Doxford, in England, has built and is building about 20 of these engines. All of them have airless, or direct, injection and will use even bunker oil with as good fuel economy as an air-injection Diesel.

The De La Vergne solid-injection engine presents two features of interest in that its volumetric combustion efficiency is about 80 per cent as high as that of an air-injection engine, based on average ratings, and the fuel consumption is as low, although the cycle is a modified Diesel. This engine uses the opposed sprays and separate combustion of the Price system. This same system is used by the Ingersoll-Rand Co. in its engines, including the locomotive engine mentioned. Fig. 14 shows a cross-section. Compression is to 350 lb. per sq. in. and the burning pressure is 500 lb. per sq. in. It has a mechanical feature that is novel in that the camshaft is driven by a silent chain, as in automobile practice.

As to the engine that presents the unique distinction of being a "production job," one exists in which the combustion-process and the combustion-chamber are of particular interest. The combustion-chamber is of the "divided" type, part of the air remaining in the main cylinder. The chamber is not as completely cooled as with the customary Diesel. The fuel burns in the first chamber to carbon monoxide, or at least some considerable portion does, for the heat liberated is too little for complete combustion to carbon dioxide. The final stage in burning takes place upon issuance into the main cylinder, where additional air is available. A fuel-consumption guarantee of 0.45 lb. is given with the larger sizes, and lower figures are achieved. A 500 lb. per sq. in. compression-pressure is used. This engine is typical of a large class eminently suited for highly reliable stationary installations but has too low a volumetric-combustion efficiency to be suitable for large marine use and probably for development into automotive use. However, a far greater amount of horsepower of this class is demanded in this Country than of any other kind at present, as the production of 3000 hp. per week testifies.

The subject matter of this paper seems to me more historical than argumentative; so, without comparative discussion as between one development and another, I have endeavored to give a composite picture and trust that the position of the Diesel engine as a prime-mover within the next few years is evident.

THE DISCUSSION

Lloyd Yost[2]:—The important point in the application of the Diesel or oil-burning engine to the automotive field is the great difference between what we have expected from an automotive engine and what we have learned to expect from a diesel engine. Consider the amount of service the average automobile engine gives and that it is regarded as satisfactory. If it operates the car for 10,000 miles, at an average car-speed of 20 m.p.h., it runs 500 hr. and we expect to overhaul it. In contrast, we expect a heavy-duty oil-engine to operate 6 or 7 days per week, every week in the year and, after 3 or 4 years of that kind of service we are willing to overhaul it. The proportion that we expect is about 40 to 1, representing the handicap we must overcome in applying the Diesel engine to automotive work.

In its application to the automotive field the main point now with the Diesel engine is its ability to use the low-grade fuel. A difference of a few points in the fuel

[2] Chief engineer, Fairbanks, Morse & Co., Chicago.

consumption when burning heavy oil makes no appreciable difference in the operating cost per year of a Diesel engine, because the oil costs very little; it is the ability to use it in a small engine that is important.

In considering this question, I find a great diversity of opinion as to what an automotive engine ought to be. For example, in rail-car application, all sorts of arrangements are used and none has been standardized. We have done more standardization in the stationary and the marine-engine fields.

The efficiency of scavenging is merely a factor that sometimes is related to the efficiency of combustion. What we need, however, is a practical engine that works and continues to work; small light-weight engines do not last long. We are trying to perfect a light engine that will stand up in automobile service as well as the heavy-duty engine does; one that will give the same kind of service the stationary engine does. We must bring the two together. The problem has not been solved but rapid progress is being made.

Mass production is coming just as soon as the American manufacturers become standardized and can find the market. That is our opportunity in this Country. They have not done it abroad, but we can do it here.

J. C. SLONNEGER[3]:—Mr. Scott has shown how the oil engine has struggled along and is slowly but surely making progress toward becoming more useful. Usefulness often determines the rate of development of any new idea. The more useful a thing is or the more people it serves, the more people are thereby interested. Usefulness may be said to be the actual personal service a thing provides. A Diesel engine is useful for propelling ships, but no one feels it directly. The automobile renders a service that is very personal; hence, it has developed rapidly. More horsepower is generated in automobiles than by all the other means. We have something like 300,000,000 hp. in automobiles, and we are building at the rate of about 50,000,000 hp. additional every year.

All of us have said, at one time or another, that the Otto cycle is inherently wrong, but we are building more Otto-cycle engines than all the other engines combined. The reason is that the Otto-cycle engine can be built in light weights and, best of all, it is flexible. If we are given a light-weight oil-injection engine that is equally as flexible as the Otto-cycle engine, the latter will be forced out of business.

What really makes an engine flexible? In an internal-combustion engine, combustion is the important thing; the mechanical, chemical and thermodynamic conditions of combustion absolutely determine the engine performance. Therefore, it must be that the Otto-cycle engine possesses a flexible combustion and that possibly the Diesel engine does not. That the Diesel engine does not permit a flexible combustion is evident after tracing the course of the fuel. Upon entering the cylinder, the particles of fuel come into contact with hot air and are ignited immediately. Then, the formation of hot gases causes a rising pressure that produces an expansion and that pushes the fresh air away. In other words, the particle of fuel must catch up with the air again and, unless the velocity of that particle of fuel is sufficient to catch the air again, the combustion stops until it does. This causes the jagged, wavy line on many Diesel-engine indicator-cards; the combustion progresses irregularly. Hence, if we follow solid injection, a definite velocity of fuel is needed to keep up with the receding air, and we must vary the size of the orifice to maintain that velocity when we throttle the load or change the speed of the engine. Perhaps the first particle of fuel burns very well, but the second particle of fuel coming in behind that must pass through some partly burned gases before it can possibly reach fresh air, unless the turbulence in the cylinder is unusual; so, the combustion-chamber must be fitted to the shape of the spray as, otherwise, the fuel will not reach the fresh air.

The old method was to put the fuel nozzle in the center of the cylinder and try to spray in all directions. That did not succeed very well with the solid injection because the quantity of fuel required varies as the square of the distance away from the nozzle, but the actual quantity of fuel injected is inversely proportional to the square of the distance; so, it was impossible to get a proper amount of fuel and air together by solid injection when the nozzle was located at the center of the cylinder. Various ingenious attempts have been made to solve that problem by devising different shapes of combustion-chamber and types of fuel nozzle, and by causing turbulence and that sort of thing; but, until we are able to get the fuel and the air together at the proper time and make the combustion occur somewhat in proportion to the speed of the cycle, that is, to the number of revolutions per minute, we will not have a flexible Diesel engine. In other words, when we get as good combustion inside the Diesel engine as we do in the Otto-cycle engine, then we shall have one equally as flexible and nearly as light because, while the parts may have to be heavier for the same size of cylinder, we shall receive more horsepower out of that cylinder, because we burn the fuel at a greater efficiency, therefore we shall not need so large an engine.

Diesel engine performance bears out some of the foregoing statements. The Otto-cycle engine burns out about 70 per cent of the air, but the Diesel engine heretofore has been able to burn out only about from 40 to 50 per cent of the air. In other words, 50 per cent of the oxygen left in the air has not come into contact with fuel although it can be burned with excessive fuel; that is, when so much fuel is injected into the cylinder that it burns the excess air. In the Diesel engine, when so much fuel is injected to reach that excess air, some of that fuel is wasted; hence, a Diesel engine can be overloaded with excessive fuel above its rated capacity but at the sacrifice of economy.

Anything that contributes to making the combustion conditions inside the cylinder more ideal or more flexible advances the art of building oil engines. I have reason to believe that perhaps within the next decade we shall see oil-burning engines that have a flexible range from 200 to 3000 r.p.m. and all the characteristics of the Diesel engine as well as many of the good points of the Otto-cycle engine such as light weight. I am certain that it cannot be held back very much longer, as the demand for that sort of thing is becoming more urgent every day and many minds are working on the problem, in this Country and in Europe.

PROF. DANIEL ROESCH[4]:—Mr. Scott spoke of the volumetric efficiency as being reduced somewhat in the Diesel engine as compared with the gasoline engine. In the Diesel engine pure air is being drawn into the cylinder during the suction stroke, while in the case of the gasoline engine some of the gasoline will be unvaporized during the suction stroke. The lowering of the temperature due to vaporization affects the gasoline engine favorably with regard to volumetric filling. That problem was recently brought to my attention by a study of

[3] International Harvester Co., Milwaukee, Wis.

[4] M.S.A.E.—Associate professor of gas engineering, Armour Institute of Technology, Chicago.

indicator-cards. One of our regular experiments for students involves the determination of volumetric efficiency by measuring the gas and the air volume entering the engine, and also the measurement of volumetric efficiency by the card. When the latter is corrected for the shrinkage of residual gases during the temperature drop of the suction stroke, the relationship of the two volumetric efficiencies will establish the temperature at the end of the suction stroke. The weight of the gas, as determined by volumetric filling from an indicator-card, corrected, and also by metering the gas and the air, is equal. Therefore, we can apply the $pv/t =$ a constant relationship and get at the temperature at atmospheric pressure following the suction stroke. By working out a number of these problems I found that considerable information is to be gained there. Temperatures below 200 deg. fahr. can be obtained in this way. The only other method that has been used for the temperature determination, so far as I know, is by means of fine platinum wires. The variation of resistance of these wires gives a measure of the temperature.

I was glad to note that Mr. Scott presented part-load conditions, a very vital thing if the Diesel engine is to be applied to automotive work. In fact it is one of prime importance, because the part-load condition is the load under which the automobile engine operates much of the time. Relative economy was also brought out by the speaker, and that is reflected in the part-load fuel-consumption curves where the Diesel engine shows very high efficiency at part load, in addition to the high thermal efficiency at full load. However, I have noticed that the automobile engine has improved this part-load economy within the last 3 or 4 years; it has improved very materially in this respect and the part-load economy-curve is flatter at the lighter load than it has been in previous years. This undoubtedly is due to somewhat higher compression and also to better vaporization and to fuel-mixture-requirement study.

Two of our students have been running tests on a Hvid engine that reflect the part-load and also the full-load curve; thermal efficiencies of 28 per cent and holding approximately that efficiency from full load down to half or three-eighths load are obtained without particular difficulty. I note the following relative thermal efficiencies: For a 500-hp. steam-plant, 10 per cent; and for a 500-hp. Diesel plant, 34 per cent. It might have been well to augment these figures with some of the lower powers and also with some of the higher powers. I understand that Chicago has large steam plants which operate on about 1½ lb. of coal per kw-hr.; the thermal efficiency is considerably higher in that case than for the 500-hp. steam-plant cited. On the other hand, steam plants of smaller power may have a thermal efficiency considerably below the 10 per cent stated.

PHILIP L. SCOTT:—Mr. Slonneger brought out a valuable point in speaking of general service. No doubt all of us are more or less dependent on the automobile in these days. I think a long time will elapse before we have a Diesel engine in an automobile but, in the case of the tractor, it was not so long ago that the horse was a better fuel burner than was the tractor engine. If an engine can be developed so that throughout its range of loads, as Professor Roesch suggests, it would have a low fuel-consumption and so be more or less an all-duty machine for general service, it would be of very great value. A number of cases can be cited. The railroad situation is one because of the inefficiency of steam power for the short haul. The Diesel engine would put it on an economic basis and that would be of great service to all parts of the Country. It is through such demands for these things that we will receive support to develop Diesel engines in smaller powers, lighter weights and higher speeds.

Regarding Mr. Slonneger's remarks on flexibility, I think the Diesel engine is more flexible than the Otto-cycle engine, so far as more power or more speed of the engine is concerned. In an injection engine, if you change the control, the very next pump stroke puts that fuel in the cylinder. I have reversed a 1000-hp. Diesel-engine in 4 sec. by pulling back a lever. I turn the air on, when the pistons are coming together, at about 800 lb.; the safety-valves blow open, and the engine stops within a few turns and begins to turn in the opposite direction. The large engines can be reversed in 10 sec. I believe you cannot reverse a 500-hp. gasoline-engine in that short space of time. If we move the small lever and throw it full over, we get so much oil at the next charge that there is a shock on the crankshaft.

Combustion is perhaps the principal problem we are working with in the matter of the high-speed engine. We have a minute fraction of a second in which to get all this fuel into contact with all the air. The Diesel engine has not a high efficiency in mixing fuel and air, as yet. I always think of the ideal condition of operation there as a torch that can be turned on and off. A current of combustible material is coming in and the oxygen is around it somewhere. When sprayed fuel is burned in the open air or, where there is plenty of air, you can see air currents coming in back of the burning zone against the fuel, and mixing with it as it comes. You can set up that double whirl. That condition is not so bad as having to force fresh fuel through a blazing zone. If you do have that condition, the fuel is very liable to break-up, you will have a detonating action, the engine will knock and the quantity of fuel consumed will be excessive.

Velocity is a most important point. The velocity of the fuel must be sufficient to reach the air, whatever shape of chamber you choose, in the limited time available. It should not take more than 10 per cent of the entire crank cycle to get all the air and fuel together. As to varying the area of the orifice, that can be done very easily. Spring forms will make the orifice area proportional to the quantity of fuel that has to pass through it.

Regarding combined Otto-cycle and Diesel engines, the higher the speed is, the more of a cross there is between the Diesel and the Otto-cycles. It seems to be a necessary combination. I may have given a wrong impression to Professor Roesch. I did not mean volumetric efficiency; I meant volumetric-combustion efficiency. By that I intended to express the amount of air that is used by the fuel as compared with the total amount in the cylinder that should be used. When the aeronautic engine is considered, it is expressed roughly in brake mean effective pressures. We can get 141 lb. per sq. in. in brake mean effective pressures in an aeronautic engine. Diesel engines, as they are rated generally, show 85 lb. per sq. in. on a four-stroke cycle. One card showed an indicated pressure of 139 lb. per sq. in. and 90-per cent mechanical efficiency. I said 120 lb. per sq. in. brake mean effective pressure, but it is 125 lb. per sq. in. That is high; it is the best I know of. But, in considering volumetric-combustion efficiency, the quantity of air that is actually used over the total air that should be used is usually about two-thirds in the Diesel engine as compared with aeronautic practice. That is one of the things we must overcome.

Concerning part-load service, an injection engine is a constant-compression engine and we all know what that means. Work has been done in regard to stratification of the fuel charge to get constant compression in an engine with a carbureter, but we do not need to bother about that with an injection engine as the pressure is constant regardless of load. That is one of the reasons for very high efficiencies at part load.

R. E. WILSON[5]:—I feel convinced that this problem can be solved as soon as the problem of mass production is solved, and that it has been held back for much the same reason. So little is standardized in Diesel engines at present that almost every Diesel engine is a special job. If the proper amount of study is devoted to the lubrication of one engine, its particular problem can be solved very satisfactorily, as has been done for a number of engines. However, after a few of these engines are built, numerous changes are made, which necessitate reopening the lubrication question. The real need is for standardizing on a few general types as soon as possible; then the lubrication problem undoubtedly can be solved, with, possibly, a few reasonable changes in design.

E. W. STEWART[6]:—Our experience in the construction of springs for the Diesel engine has been chiefly in regard to heat. The main difficulty we have encountered in satisfying those demands is in certain designs in which the springs have been placed so close to the combustion-chambers or in such position that the passage of hot gases makes it difficult to get anything that will stand-up under the operating temperatures. We have had a few cases of experimental work on the use of special alloy-steels, but for the most part, the solution of the spring question is simply to put the spring somewhere where it will be sufficiently cool. In most of the designs as they are worked out today the spring has been moved away by using leverage mechanisms of some character. The spring is kept away from the heat. So far as actual operating stresses on springs are concerned, no very serious problems are encountered; it is chiefly a matter of keeping them cool so they will not lose their temper.

[5] M.S.A.E.—Member of the research council, Standard Oil Co., Research Laboratory, Whiting, Ind.

[6] M.S.A.E.—Sales manager, William D. Gibson Co., Chicago.

W. E. WILLIAMS:—I have been trying to decide how soon we will have Diesel-engine passenger cars; I am not, as yet, much encouraged at the prospect. One feature in connection with the passenger-automobile engine of the ordinary type, is the disagreeable nature of cheap fuels. My prophecy is: No matter what the kerosene or other low grade fuel cost, as these fuels are now known, or how little the engine consumes, the man who drives an automobile will not buy a car that uses the foul smelling, greasy fuel. He will buy the gasoline-car, instead, unless a fuel is made that is less disagreeable than the gasoline of today, no matter how much he gains in efficiency by the use of the new fuel.

Another feature involved in this passenger-engine problem is air purification. Very high pressures exist in the Diesel engine and, when the Diesel engine is driven over dusty roads it will not last for the number of miles of usage that it is expected to last because of wear due to dust-abrasion of the piston-rings and the cylinders.

J. S. ERSKINE:—What is the cost of a Diesel engine as compared with the Otto-cycle engine of corresponding horsepower, say a conventional Otto-cycle engine of 50 to 75 hp.?

MR. SCOTT:—The injection engine solves one of the great present difficulties; with injection, no crankcase-oil dilution occurs. As to the costs, the Diesel four-stroke-cycle marine-type engine is about 25 per cent more expensive than the steam engine. The two-stroke-cycle double-acting Diesel engine costs about $60 per hp., which is very close to the cost of steam power. With the two-stroke cycle, I think we can cut the cost below that of the present four-stroke-cycle Diesel-engine, but that is simply a guess.

THE R 38 MEMORIAL PRIZE

THE fourth annual competition for the R 38 Memorial Prize has been announced by the Royal Aeronautical Society. This prize, which is open to international competition, is offered for the best paper dealing with some subject of a technical nature in the science of aeronautics. Other things being equal, preference will be given to papers that relate to airships and special importance attaches to papers showing original work. The paper receiving the prize will be published in the *Journal of the Royal Aeronautical Society* and becomes the absolute property of the Society.

Papers must be submitted before March 31, 1926, and can be written in either French or English. Each paper must be accompanied by a signed statement to the effect that it has not been published elsewhere and that the author will not submit it for publication until the announcement of the awarding of the prize has been published.

Intending competitors should send their names to the secretary of the Royal Aeronautical Society, 7 Albemarle Street, London, W. 1, on or before Dec. 31, 1925, with such information concerning the projected scope as will enable suitable arrangements to be made for the examination of the papers and the awarding of the prize.

WORLD COAL PRODUCTION

STATISTICS show that the world production of coal in 1924 was 1.6 per cent less than in 1913; but of the world requirements, the United Kingdom is now supplying less than 5.0 per cent, compared with 7.0 per cent. France is today producing at the rate of about 50,000,000 tons per annum, compared with just over 40,000,000 tons in 1913; Holland over 5,000,000 tons, compared with about 1,500,000 tons; and, though Germany is producing coal at the rate of between 10,000,000 and 11,000,000 tons per month, compared with 15,700,000 tons, she is producing lignite at nearly double the pre-war rate, while on an average the labor cost of production not only in that country but also in the other foreign coal-producing nations is about 40 per cent less than in the United Kingdom.—*Monthly Review* (London).

Training the Foremen of a Manufacturing Organization

By Louis Ruthenburg[1]

Production Meeting Paper

ABSTRACT

INDUSTRIAL development has out-run foreman development, in the author's opinion. He believes that management should be alive to the changed status of the foreman and that it should train him definitely to accept a broader responsibility. Clarification of the situation should start with the assumption that the departmental foreman is to be held definitely responsible for every activity that affects his department; but, obviously, he cannot be given direct authority over certain functionalized services that very directly affect the operation of his department, and he must, therefore, develop that higher type of executive ability which can obtain results without the club of direct authority. In short, instead of conceiving the departmental foreman as the master craftsman of his department, he should be looked upon as the business manager of his department.

Business management, even of a factory department, involves an understanding of many things that the foreman cannot learn thoroughly or systematically in his craftsmanship experience. Business problems usually involve one or more of three elements: technical, economic and the human. Foremen are usually most proficient in the first element and are deficient in the last two. Management generally does not recognize the desirability of training foremen in basic economic principles and in the elements of human reaction.

In planning a foreman-training program, method is initially of much greater importance than text matter. "*How*" should take precedence over "*what*." A receptive attitude on the part of the men to be trained is absolutely essential before training can be effective. Leadership acceptable to the men to be trained is another primary requisite. The training program should be actively sponsored by the highest official whom the foremen recognize as a practical manufacturing man.

Obviously, the lecturers or teachers employed in foreman training must be carefully selected. Their desirable qualifications are outlined, suggestions are made as to text material for a primary foreman-training course. The feasibility of advanced courses to follow the primary course is discussed, the results obtained by foreman training under widely varying conditions are pointed out, and the methods of foreman rating and promotion are touched upon. It is difficult to train men in foremanship after they have become foremen in name. Training should start among candidates for supervisory positions, and foreman apprenticeship is discussed in connection with the "Squad Idea."

PERMANENCE and profits usually are the major objectives of a manufacturing organization. Given a saleable product, a competent selling organization and sufficient financial strength, permanence and profits depend upon high quality and low cost of the product, as compared with the quality and the cost of competitive products. Good foremanship is an important factor in establishing and maintaining high quality and low cost.

Can the quality of foremanship be bettered by a type of training that comprehends the essential nature of the foreman's job and that is of a very different nature from the training that the average foreman has received?

This question cannot be answered until we have observed carefully the conditions under which the foreman works and have established clearly in our minds the essential nature of this job.

The Foreman's Environment and Responsibility

When we examine average conditions in automotive shops, it is apparent that processing is predetermined. Tools are designed, made, stored, issued and accounted for by specialists. Labor is hired and fired by a personnel organization. Piece-work prices or bonus payments are established by the rate department. Material is moved by direction of the dispatching organization. Machine tools are maintained by an organization independent of the operating department. Work is accepted or rejected by the inspection organization, under rules established by the engineering division.

Most of our organizations function thus. Under these conditions, what is the departmental foreman's job? Is he simply a consultant? Is he the teacher, the guide and mentor for the workmen in his department? Or, is he merely a departmental master-mechanic without clearly defined responsibilities?

To some extent, have not these specialized functions relieved the foreman of direct responsibility and supplied him with a set of ready-made "alibis"? Why should he not "pass the buck?" The complexity of manufacturing organization has increased at a prodigious rate and, while we have been adding all these fine, theoretically effective specialized-functions, our shop foremen have been given very little real training and information. Industrial development has run away from foreman development. Should we not instruct these foremen and hold them fully responsible once more for the operation of their departments?

It is highly desirable that we retain the great advantages of functionalized plant control; but, to reap the full benefit of the system, we must eliminate "buck-passing" and reduce overhead charges to the minimum. I know of no method of attaining these objectives which is as direct, inexpensive and constructive as that of training departmental foremen properly.

Departmental Management

If we start with the assumption that the foreman is to be held fully responsible for every activity that affects the operation of his department, we are immediately confronted by the fact that he cannot be given direct authority over certain functionalized services that very directly affect the operation of his department. He must, therefore, develop that higher type of executive ability which can obtain results without the club of direct authority.

[1] M.S.A.E.—General manager, Yellow Sleeve Valve Engine Works, Inc., East Moline, Ill.

He must understand the reasons for and the methods of operation of these functions. He must learn the arts of persuasion, sound salesmanship and diplomacy. In short, instead of regarding the departmental foreman as simply the master craftsman of his department, we must come to look upon him as the business manager of his department.

Business management, even of a factory department, involves an understanding of many things that the foreman cannot learn thoroughly or systematically in his craftsmanship experience. Business problems usually resolve themselves into one or more of three elements:

(1) Technical, comprising the "know how," or the practical phase
(2) Economic, including the "dollars-and-cents" relationship, or the "will-it-pay" phase
(3) Human, such as salesmanship in its broader aspects, or the "getting cooperation" phase

Foremen, by virtue of their craftsmanship training, usually are most proficient in element (1) of business management, and generally deficient in elements (2) and (3).

Economic and Human Elements

It is no more necessary that a foreman should be an economist or a psychologist than that he should be an academically trained engineer; but, if he is to assume the broader responsibilities of departmental management, he should have a working knowledge of simple economic principles and human reactions just as surely as he should have his practical trade knowledge.

By "a working knowledge of economic principles," I do not mean that the foreman should be able to discourse learnedly about the work of Adam Smith or that he should be able to define clearly the Law of Diminishing Return; but he should have a clear insight into such economic factors as equipment depreciation, tool cost, scrap charges, supply costs, supervision and inspection charges and the like in their relation to direct labor charges and total costs.

When I refer to practical knowledge of human reactions, I am trying to convey the thought that our foremen should have qualifications of leadership. They should be able to inspire enthusiastic cooperation rather than passive acquiescence among the men under their direction. They should know how to select and train and keep good men. Sound teaching ability among its foremen is a most valuable asset to an organization.

Need for Systematic Training

I sometimes think that we have fallen into the very general error of assuming that a foreman's duties are simply a logical extension of the craftsman's duties. Certainly, the average foreman has had no systematic or intensive instruction in any science or art other than those relating to his craft. The average foreman is simply a skilled craftsman, naturally endowed with a little more intelligence or ambition or stamina than his fellow workmen, all essential characteristics in a foreman; but, without systematic training, his knowledge of industrial tradition and principle, of simple economic values, and of the art of dealing with men in positions subordinate, coordinate or superior to his own, must necessarily be accidental, instinctive or non-existent.

That foremen function at all effectively is a great tribute to average human intelligence and adaptability. What actually happens is that the successful foreman is forced by his environment, after he has become a foreman in name, to absorb sufficient information beyond his trade knowledge to permit him to "get by" in competition with other men who have been as inadequately trained as himself. It must be admitted that such a process is intolerable in a day in which waste and lost motion are abhorred and in an industry that boasts of high quality and low cost.

Feasibility of Foreman Training

Having examined some of the conditions surrounding modern foremanship, let us consider briefly what can be done in a practical, hard-headed way toward supplementing the average foreman's qualifications by systematic training. Many attempts at foreman training have either failed or produced indifferent results. These failures prove little except that wrong methods were employed. The fact that after innumerable attempts I cannot drive a golf ball 300 yd. does not prove conclusively that it cannot be done, nor even that I cannot learn to do it. It simply proves that I have not learned to apply the proper principles. Just as certain principles must be mastered before anyone can hope to drive a golf ball successfully, certain principles involved in foreman training must be observed if satisfactory results are to be attained. I cannot drive a golf ball very far with the wrong end of the club. Neither can we force knowledge into a man's being. Education is a "leading-out" process, not a "forcing-in" operation. Many attempts at foreman training have failed because this elementary principle has been disregarded.

In the rush days of 1919, business was booming. Materials were scarce, transportation facilities were inadequate, costs were increasing and labor turnover was very high. We did not know what to do, but we knew that the condition required correction. A salesman sold us the idea of a Foreman's Training Course and we decided that the company would share the cost of the course with the foremen. We immediately called a meeting of the superintendent, the employment manager and all the foremen. We told our foremen that we were going to teach them foremanship! Then we turned the whole thing over to the superintendent and the employment manager and went back to appeasing customers, jacking-up sources of supply and cussing the railroads for slow deliveries. Did our plan work? It did not. Suppose, for example, a case of the man who had been foreman of the turret lathes for the past 6 or 8 years, and that, without warning or preparation, the boss had said to him: "We are going to give you a chance to learn foremanship. Look, here is a book about it." Inasmuch as "the boss" was talking, the foreman would not talk back, but without any doubt he would think the boss to be temporarily insane. We can imagine the man's soliloquy: "Where did the boss get that stuff? Teach *me* foremanship? Why, haven't I been holding down a foreman's job for years? I'd like to see the bird that can tell me anything about turret lathes!" Of course the foreman would attend the classes, because he would figure that: "A foreman has to put up with a lot of foolishness in his shop, anyhow, to keep from getting in wrong. So long as the rest of the bunch stand for it, why should I pass up a good job? But, *learn anything?* Say, don't make me laugh! You don't learn how to be a foreman out of a book. What do those white-collar birds know about making a bunch of bums get production out of a string of turret lathes, anyhow?"

With such a lack of receptiveness on the part of the men to be trained, is it remarkable that the result of "foreman training" has in some cases left much to be desired? *Until an attitude of enthusiastic receptiveness exists, or has been created among the men to be trained,*

attempts at training will produce disappointing results. Then it must be remembered that the best training results can be expected only under able leadership and strong personal inspiration. It should be generally recognized among the foremen that the general superintendent, or the works manager, or the vice-president in charge of production, or even the general manager or the president himself are enthusiastically interested and believe firmly in the project. A leading company official should take enough time to understand the subject, talk to the foremen about the possibilities and supervise the program.

Foreman training is of vital importance to the organization. It is a man's job. Although the routine work must be delegated in large part to an able subordinate, this subordinate must have the boss's enthusiastic support and help. And be sure that the company official who gives this matter his attention is a practical manufacturing man. In this particular matter, foremen are usually, and for obvious reasons, doubtful of leadership of other types.

Then be sure that your routine lecturer is a *teacher*. He must command respect for his knowledge and ability. He must be able to explain abstract principles by concrete illustration. He must know your organization methods intimately. Other able speakers on special subjects should be enlisted to relieve him from time to time. Enlisting the enthusiastic interest of the foremen, strong leadership and able teaching personnel are all of utmost importance. In the initial stages, at least, method is more important than text matter. *"How"* takes precedence over *"what."*

Text and Lecture Material

In selecting or preparing text-material and lectures, it should always be kept distinctly in mind that, while we are endeavoring to teach *principles*, an average mind thinks in concrete terms and, therefore, finds it difficult to absorb abstract ideas. Consequently, every principle or abstract thought presented must be immediately, and as graphically as possible, illustrated by some concrete practice or parallel with which all the men in the class are familiar. Most of us are not readily acquisitive students. Hence the need for vivid, practical illustration. Such illustrations can best be drawn from your own plant practice. If you do not prepare your own text material, you must depend upon your lecturers and teachers to impress the principles and facts set forth in the text by graphic examples drawn from specific practice with which the foremen are intimately familiar.

The initial text-material and lectures may well deal with the evolution of industry, starting with the story of individual craftsmen and their guilds, cottage industries, the change wrought by the great inventions of a century ago, and tracing the division and subdivision of labor, with its ever increasing specialization, to the modern system of functionalized control. From this beginning it is an easy transition to an explanation of modern methods of processing, plant layout, machine-load analysis, stock control, planning, incentive methods of wage payment, time study, job analysis, methods of selecting and teaching efficient workmen, or any subject matter that may appeal to you as being a desirable part of your foreman's knowledge and mental equipment. Let your text matter present definite information as interestingly as possible. Inspirational preachment should be injected sparingly, if at all. It is probably safer to depend upon a verbal spell-binder if such spiritual food is considered indispensable.

The successful application of such methods and text material as I have described has been demonstrated in large organizations. Similar methods have been used successfully for training groups of foremen from small and greatly diversified industries.

When training is soundly started with any group, it has a tendency to be self-perpetuating in interesting and constructive developments. To cite only two examples with which I am intimately familiar: Foremen and superintendents at the Delco plant in Dayton, Ohio, have continued their classes with great enthusiasm and profit for 5 years, advancing each year to new and interesting studies of industrial subjects; and a class of less than 100 foremen from diversified industries which met in the Dayton Young Men's Christian Association 5 years ago has evolved into the Ohio Federation of Foremen's Clubs, a wonderfully fine organization of more than 3000 men.

The *feasibility* of foremen training has been proved in so many varied industries and under such widely different conditions that the adoption of a training program is largely a matter of putting it into effect with proper regard for a few basic factors carefully adapted to your own conditions.

The Squad Idea of Foreman Development and Promotion

Training the foreman after he has become a foreman in name presents some interesting and difficult problems, because we are trying to add certain qualifications that the man should have had before he was given his foreman's job. He should have attended an intensive training school after he had learned his trade thoroughly and before he was put in charge of men.

Let us now examine one or two successful attempts to establish definite training in foremanship preliminary to assignment to supervisory jobs, to cause prospective foremen to serve apprenticeships in foremanship. A number of years ago the Goodyear Tire & Rubber Co. organized what is known in their plant as the Flying Squadron. This organization has for its membership men who show promise of developing into successful plant executives. They are imbued with the high ideals of the Company. They are thoroughly grounded in all phases of processing and of plant routine and in the fundamental principles of successful manufacturing. When men are graduated from the Flying Squadron into minor foremanships, they have built foundations capable of sustaining successful careers.

A similar plan has been in effect for some years at the Dayton Engineering Laboratories plant. The scheme is fairly simple. Candidates for the "Squad" usually are drawn from among the departmental job-setters or from applicants who have had technical-school training. With 2000 people on the factory payroll usually six or eight men are on the "Squad." Foreman turnover at the Delco plant is very small. The squad men are trained in motion study, rate setting, stock handling and accounting and the like by being assigned to jobs in these departments. They are given definite training in foremanship, during which they are required to read certain text material, attend lectures and pass examinations. When a vacancy among the "job foremen" occurs, a squad man usually is given the position. Squad graduates almost invariably become successful foremen. If a man's characteristics are such that he cannot become a successful foreman, he is eliminated from the Squad long before graduation and promotion. It costs considerable money to hire and fire foremen. The fact that careful

training greatly reduces foreman turnover has been demonstrated very thoroughly.

Foreman Rating

Nearly 6 years ago I had the good fortune to establish contact with Dr. Walter Dill Scott and his able staff immediately after their very interesting personnel work in the Army had been interrupted by the signing of the Armistice. Under the immediate direction of Dr. J. W. Hayes, we set out to discover whether methods, similar to those used so successfully in the Army, had any considerable value in our industry.

Among other things, a scheme of executive rating, very similar in principle to the Army plan for officer rating, was developed. This has been continued as a means of foreman rating. There are seven qualifications considered under this scheme; namely:

(1) Appearance and Manner
(2) Technical Ability
(3) Initiative
(4) Leadership
(5) Planning Ability
(6) Cooperativeness
(7) Ability in Developing Men

The division superintendents rate each of their foremen and job foremen under this plan every 6 months. Frequently, they ask the general superintendent to make independent ratings as a check upon their own. The foremen are told in a friendly and helpful way just how they fall short of perfection, and suggestions are made to them as to ways and means for correcting their weaknesses. When promotions are to be made, the ratings of the candidates have a very considerable influence on the choice.

The rating scheme is analytical; it reduces the influence of prejudice and is the means of upgrading and developing the foremen by placing their deficiencies frequently before them. Mental-alertness tests are used as one means of choosing candidates for the Squad and as a supplementary method of rating foremen.

While such methods as these are of great value in large organizations, where it is impossible for one executive to maintain close personal contact with all foremen and department heads, they are not without interest in smaller organizations as a means of checking the boss's opinion of the men with whom he does have close contact. Most of us are willing to admit that we have a sort of God-given intuition that permits us to choose good men for responsible positions. Some men, undoubtedly, do have a natural gift or a cultivated ability for sizing up capabilities in other men with uncanny accuracy; but, with most of us, our pride in ability to pick winners is the result of remembering our successes and forgetting our failures. When we try to define the reasons for thinking a man will be a winner or a "dud" in a future position, we often find that our opinions and prejudices are not entirely dependable. Most of us buy pig iron or steel or fuel to definite specifications, subject to analysis in our own laboratories. Is it not at least equally important to select and promote men under "specifications" as nearly exact as it is possible to define them and subject to analysis as accurate as the undeveloped state of the art permits?

Space limitations compel me to cover the subject rather broadly, in very general terms and simply to outline one method of thinking about a very big subject, although there are many phases of the subject which I should like to discuss in detail and at length.

The importance of good foremanship as a means of reducing cost and of increasing quality must be obvious. It is apparent that traditional methods of foreman training are inadequate when the complexity of present industrial organization is taken into account. If the departmental foreman is to assume a position of maximum value under modern conditions, the problem of training present and future foremen must receive careful study and the economic and human elements of his job must not be neglected. Enough has been accomplished to demonstrate the feasibility and value of such training.

FARMS AND CROP AREA IN THE UNITED STATES

THE results of a survey just completed by the Department of Agriculture indicates that the number of farms in the United States was smaller by about 30,000, or 0.50 per cent, in 1924 than in 1923, while a decrease of about 1,200,000 acres, or 0.33 per cent, also occurred in the amount of land devoted to crops. Of the area withdrawn from crop use about 1,000,000 acres was employed to provide additional pasture for horses and cattle of various kinds.

The survey shows that some farmers in nearly all parts of the Country are extending the cultivated area either by clearing, drainage or dry farming, but that for the Country as a whole many more farmers are allowing plow-land to be idle. The area of idle plow-land, excluding summer fallow, is placed at about 25,000,000 acres, which is about nine times as much as the area brought into cultivation for the first time in 1924.

The decrease in the number of farms, though small, is general in central and southern Georgia and southeastern Alabama, where it ranges from 1 to 10 per cent; in much of Michigan and Missouri, where it averages about 2 per cent; in most of Colorado, in southeastern Idaho and eastern Washington, where it ranges in general from 1 to 5 per cent. Undoubtedly, some of this decrease is accounted for by the consolidation of farms into larger economic units.

An increase in the number of farms, on the other hand, is notable along the northern and western margin of the Cotton Belt, where the boll-weevil infestation is less severe than to the south; in the lower coastal plain of the Carolinas; in southern Florida; and in Texas. The increase in various parts of these regions ranges from 1 to 10 per cent. Much of Minnesota, eastern South Dakota, most of Nebraska, and central and southern California likewise show an increase in the number of farms.

The decrease in crop acreage was greatest in western Georgia, southeastern Alabama, southern Mississippi, western Maryland, Pennsylvania, southern New York, Michigan, southern Illinois, western Kentucky, and much of Missouri. Decreases in crop land also characterized most of the districts west of the Rocky Mountains, except Utah, central and southern California, the Willamette Valley of Oregon, and the Yakima and Chelan Valleys of Washington.

Increases in crop land are indicated by the reports from Massachusetts and from the Atlantic Coastal Plain from New Jersey to southern Florida. The northern margin of the Cotton Belt also shows a notable increase of land in crops all the way from southern Virginia to Oklahoma, and in Texas, especially the western part of the State, the increase in crop acreage has been rapid. Extension of the crop area during 1924 is notable also in the Great Plains region from Montana to eastern New Mexico, except in southeastern Wyoming and southeastern Colorado. Most of Utah and California likewise show an increase in crop acreage.—*Economic World.*

Frontier Facts in Air Transportation

By Lieut. J. Parker Van Zandt,[1] U.S.A.

Illustrated with Charts

MARK TWAIN once defined a newspaper as "a small body of information entirely surrounded by advertisements." Similarly, aeronautics might be described as a small body of facts entirely surrounded by opinions. Indeed, we might go further and say "almost entirely obscured by opinions," for surely the air-transportation field today is surfeited with prophetic visions, panaceas, and all manner of talk, while the bed-rock of facts, the only safe foundation for rational thinking, is being sadly neglected. Perhaps what we need most in commercial aviation is to stake out the frontiers of this body of authentic, undisputed facts; we need to know what is solid ground.

Rational opinion is the interpretation of facts in the light of sound judgment and experience. It starts from the known and predicts the future by a process of conservative extrapolation. The known facts are the bricks. The mortar that unites the bricks in a useful structure is the trained intelligence that brings to the task the best of critical perspective and experience; but we cannot begin to build until we have the bricks.

Where can we find the facts? There is only one source—actual experience. The accumulated experience of the air-transportation ventures of the world is the factory in which these "bricks" have been and are being made. It is the laboratory of the air-transportation engineer. Our task, then, is to isolate and label the facts developed in this laboratory.

The four accompanying charts are an attempt in this direction. Fig. 1 is a graphical picture of the extent of the air-transportation "laboratory." More than 28,000,000 miles has been flown in Europe and the United States to Jan. 1, 1925, in regular scheduled air services. These 28,000,000 miles represents the primary source of operating facts.

Fig. 2 is a graphical picture of the world experience in air traffic. In 6 years more than 51,000,000 lb. has been carried by aircraft over established routes. A careful analysis of this experience will give us the body of facts we so much need regarding the air-traffic problem.

Thus, Figs. 1 and 2 give a bird's-eye view of the sources of our facts, while Figs. 3 and 4 suggest some of the basic facts that a study of these sources will disclose. No claim is made for their completeness. They are set down as indicative of the character of research that must be carried out if we are to separate the authentic lessons of experience from the welter of ungrounded opinion. They represent only a beginning in this work of scientific fact-finding.

It may be well to include a caution against indiscriminate conclusions from the facts on safety and reliability shown in Figs. 3 and 4. They are *selected* facts and a knowledge of the conditions of operation under which these experiences accrued is essential to their proper interpretation. This knowledge is the "mortar" referred to in the foregoing analogy; it is the factor of personal perspective and understanding that determines the value of an opinion, apart from the facts upon which it is based. Granting, however, that these are selected facts and hence only a partial picture, they form a hopeful basis for holding an optimistic view regarding the ultimate future of air transportation.

If this brief statement serves to stimulate others to attack the aeronautical problem in a spirit of impartial fact-finding, it will have amply served its purpose. Commercial aviation is starved for facts, but fortunately most of the information vitally needed is available in the world if enough trained and willing workers can be enlisted to collect it and present it intelligently.

An opinion that does not carry with it an essential agreement with all the available facts is like a taxicab without a passenger; in the words of Christopher Morley, "It is only the taxi with a fare inside that spins briskly to its destination."

[1] S.M.S.A.E.—Air Service, City of Washington.

FIG. 1- MILEAGE FLOWN OVER ESTABLISHED ROUTES CARRYING PASSENGERS, MAIL OR GOODS

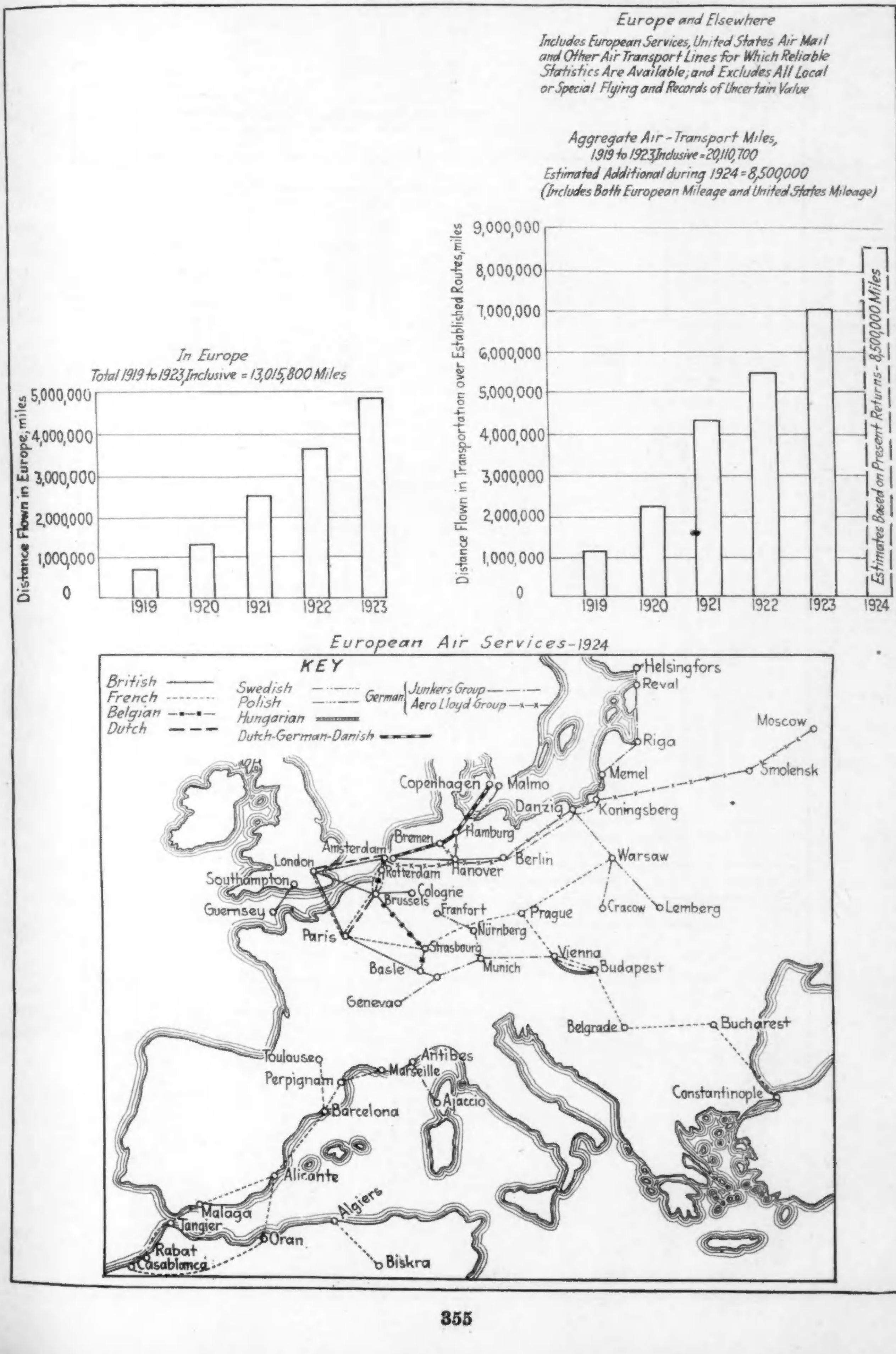
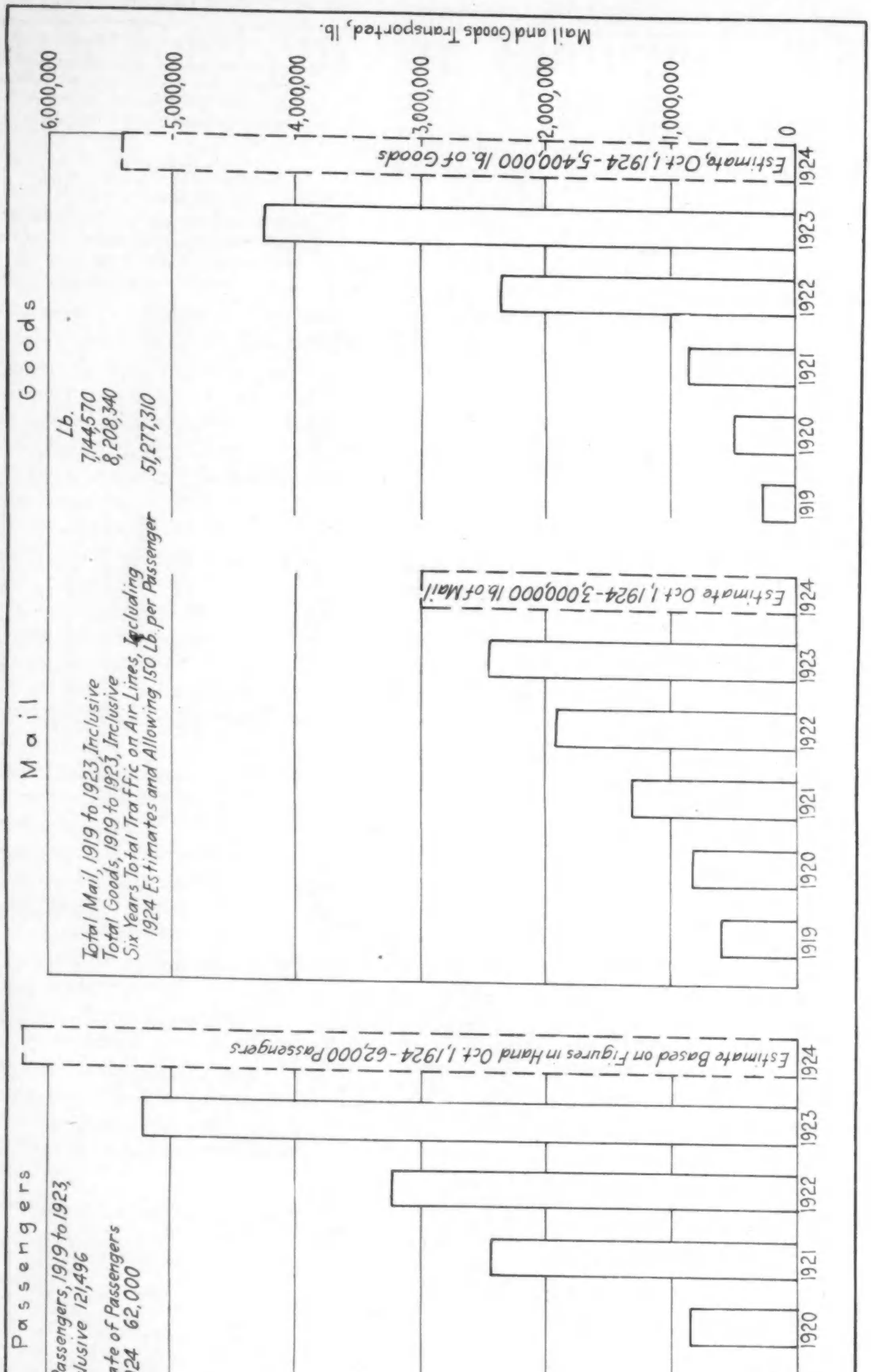


FIG. 2—PASSENGERS, MAIL AND GOODS CARRIED BY REGULAR AIR TRANSPORTATION SERVICES



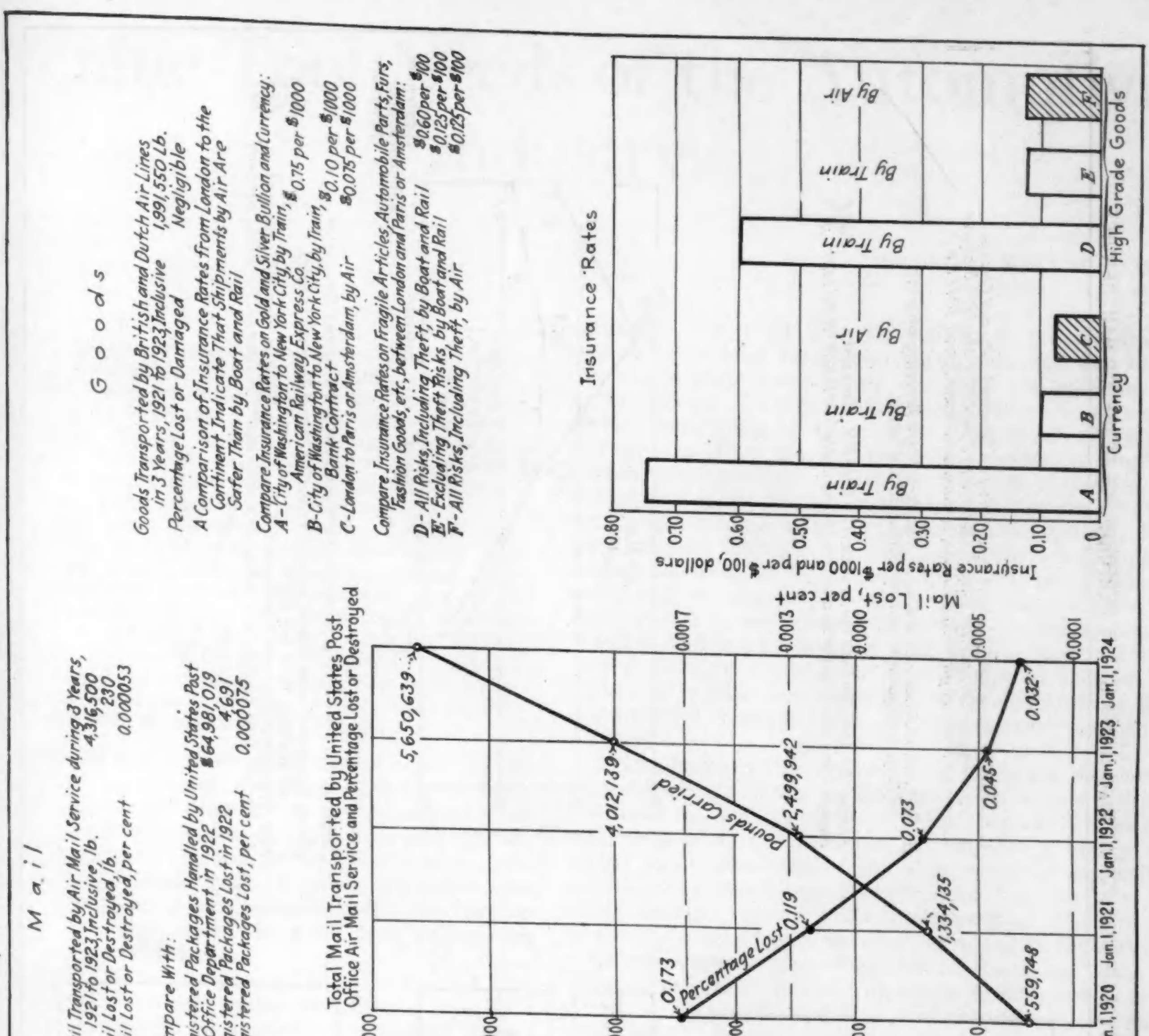
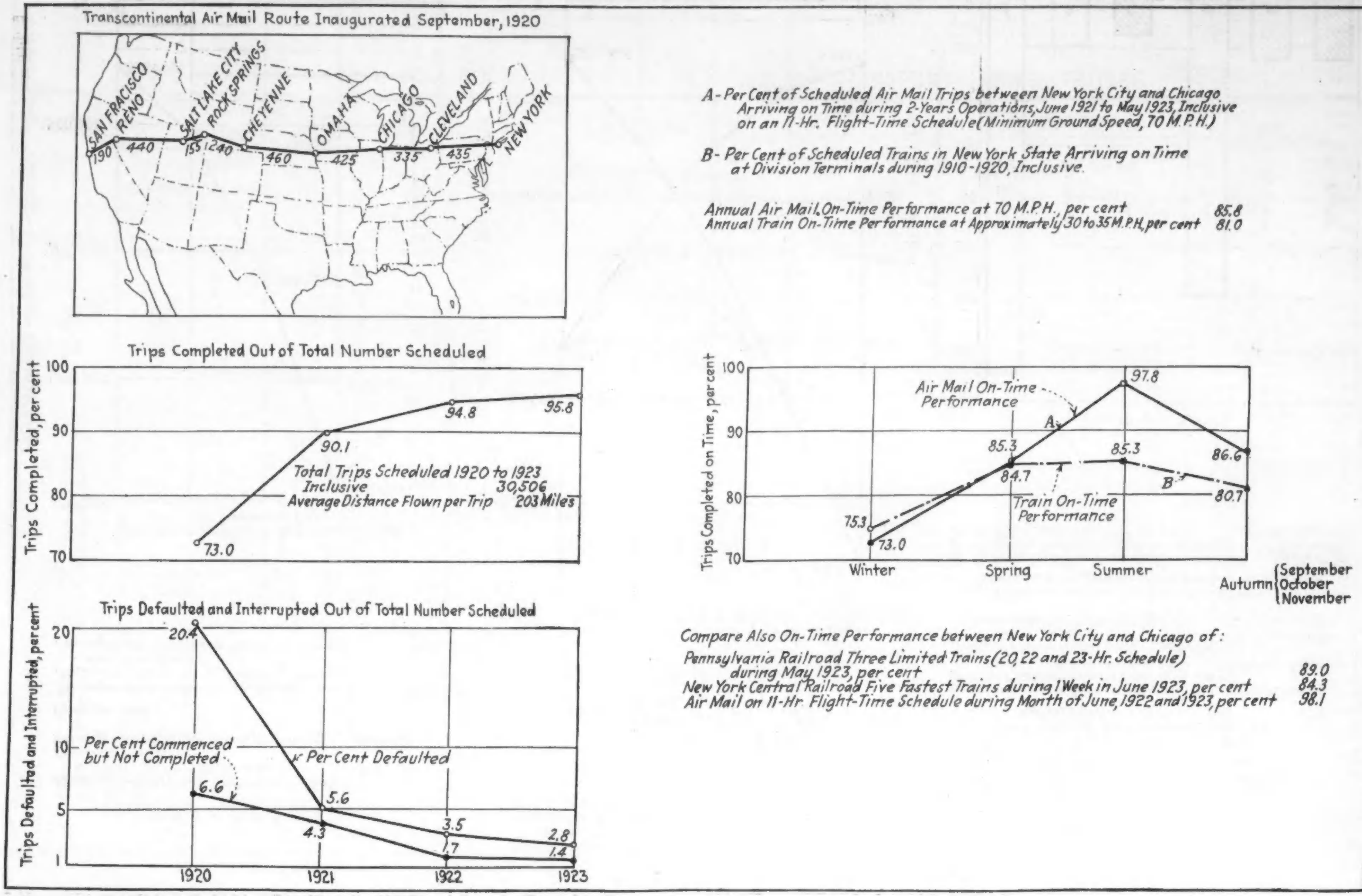


FIG. 3–EVIDENCE REGARDING THE SAFETY OF PASSENGERS, MAIL AND GOODS CARRIED BY REGULAR AIR TRANSPORTATION SERVICES

FIG. 4—EVIDENCE REGARDING THE RELIABILITY OF AIR TRANSPORTATION AS SHOWN BY THE PERFORMANCE OF THE AIR MAIL SERVICE



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Machine-Tool Needs of the Automotive Industry

By R. M. Hidey[1]

Production Meeting Paper

ABSTRACT

RAPID automotive-engineering developments and keen competition, fostered by public demand for better and cheaper transportation, have provided the impetus for most of the development in the machine-tool industry for the last 15 years, and the author analyzes present needs for machine tools as a basis for his recommendations for improved methods of business procedure and better cooperation.

After discussing the relative merits of single and multi-purpose machine-tools, matters relating to the safeguarding of such tools, the benefits attendant upon better cooperative effort and the necessity of making greater expenditures for the development of the machine-tool industry, the author advocates active pioneering in fresh fields that offer greater opportunities for machine-tool usage, rather than dependance upon replacement business, and makes five specific recommendations to machine-tool builders.

A DISCUSSION of the machine-tool needs of the automotive industry should be of value in determining its most urgent ones, and a concise statement of such automotive needs should be a guide to the machine-tool industry in the satisfying of them. The fact that we are discussing the situation indicates a need for the clarification of our demands, and also demonstrates that our requirements have not been, and are not being given proper attention.

Development in the machine-tool industry started with the advent of the steam engine and, for a time, was closely associated with steam-engine progress. For a long time activities were confined mostly to perfecting existing machines, and no further striking development occurred until the automotive industry began to make demands for interchangeable manufacturing which the existing tools could not meet. The demands of the automotive industry have given an unparalleled impetus to, and have been responsible for, most of the development in the machine-tool industry during the last 15 years. This has been due to rapid automotive-engineering developments and keen competition, fostered by public demand for better and cheaper transportation. Without the assistance of the machine-tool industry, the automotive industry would never have reached its present stage of development. In fact, the friendly cooperation that has existed between the two industries is responsible for the success of both of them.

Single or Multi-Purpose Machines?

A question that is causing considerable concern to many equipment engineers is whether to use single or multi-purpose machines. Originally, a machine capable of handling a wide variety of work was used and then, when that machine was used only as a single purpose machine, a considerable investment remained idle. Machines that are of a strictly single-purpose character are economical only when production is reckoned in large numbers. The most general demand is for machines that are especially adapted to high production and that also can be adapted readily, by changes in tool equipment, to the making of similar parts of another model or even to the performing of other work. Too much attention has been paid by the machine-tool industry to single-purpose machines that satisfy the demands of those concerned with large production of a limited line only. However, a real demand exists in the automotive industry for multi-purpose machines as, with frequently varying production-demands, it is at times decidedly advantageous to be able to change jobs easily from one machine to another, to another department or even to another plant. Standardized machines fitted with special tools for the performance of a variety of jobs should be cheaper to build and operate, and would be a source of profit to the machine-tool builders and to the automotive manufacturer.

A standardized line of machines offers the following sales arguments: lower initial cost, more remote risk of obsolescence, and higher second-hand value. It would also be possible for the user to maintain a supply of repair parts, resulting in the elimination of expensive machine-tool repair departments, and thus be able to effect prompt repairs. The multi-purpose machine is particularly valuable in the small shop and in the service machining-departments of automotive factories; also, in automotive service-stations, of which 70,000 exist in this Country. This combined field is of tremendous size and, consequently, permits complete standardization with its resulting economies for both the builder and the user. Standardization of this type of equipment is attempted by all large-quantity manufacturers operating branch service-stations, but standardization is only successful when machine-tool service is universal.

Safety Measures

The failure of machine-tool builders to equip machines adequately with safety guards increases installation costs to a distinctly unnecessary and uneconomical extent. It is necessary for us to spend from $20 to $75 to make new machines safe for our men to operate. The builders of machines should be able to equip them with safety guards more satisfactorily and cheaply than the customer, as a standardized practice can be followed for their individual product. The net result would be that all machines would be properly guarded and a decided economic saving attained. Under existing laws, it is possible for machine-tool builders to sell machines in Ohio, which, in the same unguarded condition, could not be sold in New York State. As a consequence, the users are forced to provide safety equipment. The automotive industry, being the largest user of machine tools, is thus called upon to spend large additional sums of money for guarding machines, as it is generally required that machines should be guarded for safety rather than merely for conformance to laws. A more general application

[1] Works manager, White Motor Car Co., Cleveland.

and standardization of guards would greatly reduce the customers' burden.

Cooperative Effort

Considerable stress has been laid upon the cooperation existing between the machine-tool builders and the automotive industry. The possibilities of this cooperation, however, are only beginning to be realized. A characteristic, which we in the automotive industry are peculiarly fitted to recognize, is that considerably more cooperation has existed between machine-tool builders and their customers than between the machine-tool builders themselves. Manufacturers in the automotive field freely give information to competitors as well as to others, and permit full access, except to the research and the experimental departments, to their factories. A high degree of cooperation thus exists which often results in the solution of difficult problems and the perfection of processes. This cooperative spirit does not exist in the machine-tool industry. However much the builders have cooperated with the automotive industry, they themselves have not got together with a comparable spirit for the working out of mutual problems. The desire to excel has predominated to the exclusion of the cooperative spirit, which would have resulted in stabilizing the machine-tool industry.

The natural development of the machine-tool industry actually has been retarded because of its sphere of coöperation being confined principally to the users of its product. The machine-tool industry is entirely too dependent on its customers for new ideas and applications; whereas, it should lead in the industrial field. The designing phase of machine tools should be given the same careful study that the automotive field has given to its problems, and it is thus that a wider field for its product could be created. Progressive automobile manufacturers have to forecast to an extreme degree of accuracy, first, the number of vehicles which they can sell for months ahead; and second, whether their customers will want power, economy, safety or speed. The design, research and experimental departments thus have to be considerably in advance of actual production.

Expenditure for Development

The automotive industry spends millions of dollars yearly in designing and experimenting, while the machine-tool industry is not spending a proportional amount on developments of machine tools. Instead of pioneering actively, builders often are content simply with replacement orders for machines which have worn out. No less an authority than Ernest F. DeBrul, general manager of the National Machine Tool Builders Association, points out that, production of machine tools being at a normal rate but with no appreciable rate of expansion, "the machine-tool industry depends rather upon replacement business than on new industrial developments." This statement indicates clearly the attitude of the industry; it stands waiting to take orders and is not pioneering actively in new fields or regarding new and better methods.

Especially has testing been thrown upon the buyer, although it is a burden that properly should be borne by the builder. Generally, the builder calculates a certain performance of a machine that he places upon the market and, after the machine is delivered, a period varying from a few days to several months is spent in trying to secure that performance. My company recently purchased a machine and, failing to get the guaranteed performance, called for the builder's demonstrator. He remained at our plant for several months before results were attained. This is a situation for which the machine-tool builder should assume a definite responsibility instead of passing it on to the customer. Recently, we rearranged our entire engine division and, to test certain machines that we intended purchasing, we sent flywheels to one builder, camshafts to another and other parts elsewhere to make reasonably sure that the machines we were purchasing would perform, before placing them in our factory. We are probably more exacting than the majority of manufacturers, but the examples indicate the extent to which we must go to secure machines that perform according to our specifications. If the machine-tool builder would analyze his buying public and its needs, he would have much less to rectify after the machines were on the market. Today, production demands working to very close limits which, at the White Motor Co., means limits of ten thousandths of an inch. A thorough analysis of the needs of the automotive industry will give the machine-tool builder greater and more stable profits and will increase his service to the user.

Standardizing and Balancing

We note with satisfaction that the committee working under the auspices of the American Society of Mechanical Engineers and the National Machine Tool Builders' Association has made considerable progress in the standardization of T-slots, which should save thousands of dollars for the industry. The automotive manufacturers would be pleased to see standardization worked out for such features as spindle noses, internal and external turret-holes, lead screws, working heights and standard-machine data-sheets. These are not salient features of a machine and would not jeopardize its sale, yet a manufacturer who has a large diversity of machines of a similar make would be able to reduce his cost appreciably if such features were standardized.

The balancing of moving parts has been almost entirely neglected by machine-tool builders. The vibration of moving parts such as gears, wheels and shafts, which are seldom balanced, is frequently excessive and materially decreases the life of the machine. This improvement could well supplement the other standardization that we have recommended.

Summary

In summarizing what the automotive industry needs in the way of machine tools, we desire to make the following specific recommendations to the machine-tool builders:

(1) Develop multi-purpose machines capable of using special tool-equipment adapted for quick change-overs

(2) Safeguard all machines, so that they can be put into immediate operation without extra expense to the customer

(3) Balance all moving parts properly, so that vibration will be reduced to the minimum

(4) Continue cooperating with the automotive industry. Furthermore, actively cooperate with each other, as the free interchange of new ideas and developments is of infinite value to industry as a whole

(5) Study the demands of your market and analyze the needs of the automotive industry, not only for today but for the future as well, so that your dependence on replacement orders may give way to active production for analyzed needs

History of Automotive-Clutch Development

By E. E. Wemp[1]

Cleveland and Detroit Sections Paper *Illustrated with* Drawings

ABSTRACT

REVIEWING briefly the history of the automotive clutch and summarizing the most interesting achievements in clutch design during recent years, the author discusses friction facings and says that the development of the asbestos-base friction-bearing has made possible the multiple-disc dry-plate and the single-plate types. For severe service, the qualifications of a satisfactory friction-facing are density of structure, together with a reasonably high tensile-strength; the coefficient of friction should be high and fairly constant over a wide range of temperature; the facing must be able to withstand high temperature without deterioration; the impregnating compound must not bleed out at high temperature; and the permeation of the impregnating solution must be complete so that the wear resistance is constant throughout the thickness of the facing. The molded and the woven types of facing are treated at length.

Engagement methods, cooling and thermal efficiency, adjustment, methods of control, the lubricating of release sleeves and balancing are described. Since the clutch virtually converts engine torque into heat during the period of slippage just previous to full engagement, and since the heat must be dissipated through the clutch mechanism, the thermal efficiency of a clutch is of great importance. The severe service required of motorbuses has emphasized the importance of having a clutch rid itself of the large quantity of heat generated as a result of its frequent usage and, from his experience, the author concludes that:

(1) If careful consideration is given to the subject of thermal efficiency, the unit pressure of the facings is unimportant over a wide range of pressures

(2) As a result of conclusion (1), it is believed that a single-plate or a two-plate clutch is the logical design for heavy-duty service. This is largely because it is much easier to provide for the necessary masses of absorption metal in these clutches than in the multiple-disc type

(3) The masses of absorption metal should be carried as a part of the flywheel weight

(4) Cast iron is the best metal to use as a friction surface for engaging the facing. The free graphitic content of cast iron provides a slight lubricating effect and permits the surfaces to attain a smooth high polish

(5) With their present knowledge of the subject, the engineers of the Long Mfg. Co. attempt to provide two elements for increasing the thermal efficiency of the clutch. A considerable mass of metal is provided in the driving discs, and this mass is designed to provide a large exposed area for a surface radiation. The mass serves as a reservoir that absorbs a large number of heat units without raising the temperature of the driving disc too quickly

A BRIEF review of the evolution of the automotive clutch reveals three important changes in clutch types in the last 20 years. At the beginning of this period, clutches of the cone type were commonly used. After they had held sway for a number of years, the multiple-disc, metal-to-metal type, running in oil, made its appearance and robbed the cone type of some of its popularity; but it was not until 1910 or 1911, when the multiple-disc dry-plate type made its appearance, that the second important step in clutch design was reached. For the next few years, the cone and the dry-plate multiple-disc types contended for popularity, with the advantage gradually leaning toward the dry-plate type. This was the situation in 1915, when the "single-plate type" put in its appearance and it solved many perplexing problems. By this time, the industry was well established, mass production was more than a name and it demanded better units for less money. The operator also demanded easier operation and the new single-plate type, possessing both qualifications, rapidly came into prominence. It has displaced the cone type on most of the cheaper production cars and, because of its lower cost and reasonable serviceability, has made serious inroads in the multiple-disc-type field for use on cars of the medium and the higher priced models.

The advent of the single-plate clutch marks the third and last important change in clutch types. It is interesting to note that no new types of clutch have been developed during the last decade. The advancement during this period has been in the way of refinements of design and of developments of materials used in the existing types of clutch. The most interesting achievements in clutch art during recent years have been improvements in engagement methods, thermal efficiency, the development of non-adjustable clutches, push-type control for single-plate designs, release-sleeve designs, balancing and its effect upon design, and friction facings and their characteristics.

Friction Facings

Development of the asbestos-base friction-facing has made possible the multiple-disc dry-plate and the single-plate types of clutch. The automotive industry owes a debt of gratitude to those who developed this type of facing for, without it, a plate type of clutch as we know it would be impossible. A good friction-facing in a properly designed clutch should permit smooth flexible engagement over a wide range of speeds and be able to withstand hard and continuous service over a long period. These two characteristics do not always go hand in hand.

For good engagement, the necessary qualifications of a

[1] M.S.A.E.—Clutch engineer, Long Mfg. Co., Detroit.

facing are yieldability under pressure and a close limit of parallelism. The first is a function of the construction of the facing and is inversely proportioned to its density. The second is purely a manufacturing problem and in every design is practically independent of the type of facing that is used.

For hard service, the qualifications are density of structure, together with a reasonably high tensile-strength; the coefficient of friction should be high and fairly constant over a wide range of temperature; the facing must be able to withstand high temperatures without deterioration; the impregnating compound must not bleed out at high temperature; and the permeation of the impregnating solution must be complete so that the wear resistance is constant throughout the thickness of the facing.

Two Classes of Friction Facings

Friction facings are divided into two general classes, molded and woven. The so-called molded type of facing is really a misnomer, as it is actually cut from a rolled-asbestos sheet. This sheet is practically pure short-fiber asbestos with just enough starch added to facilitate the process of sheeting. After the sheets are dry, they are rolled down approximately to the gage of the finished facing, enough extra stock being allowed to take care of grinding. The facing rings are then cut from the sheet by dies in an ordinary punch press. The rings are next treated with the impregnating solution and placed in a furnace for curing, which process requires several hours. After cooling and straightening, the rings are ground inside and out to finished size and are rough ground on their surfaces. The next operation is drilling and countersinking the rivet holes; after this, they are finish ground to thickness. The resultant facing has great denseness, due to the rolling process in the sheet, the quality agreeing with the specification for wear but not for that of engagement, where yieldability is required and good tensile-strength. The same quality of density permits the facing to be ground to close limits of parallelism in accordance with the requirements of any specific case.

The coefficient of friction in facings of the molded type will vary according to the impregnating solutions used and the effect of temperature on the coefficient of friction will also vary from the same cause. However, facings of this type may be found that will answer both specifications for the coefficient of friction. The qualification of being able to withstand high temperatures is one of the chief assets of the molded facing. This is due to the fact that its body is practically pure asbestos and contains no foreign substance to char or burn out, either in the curing process or in actual operation. The degree of permeation of the impregnating solution is again a matter of the selection of facing, but facings can be obtained in which the permeation is complete. The use of short-fiber asbestos in the manufacture of molded facing, combined with the fact that such facings can be fabricated by press operations, permits them to be sold at very reasonable prices. The molded facing, when properly made, answers all the requirements for hard continuous service and makes it an ideal facing to use where serviceability is the paramount consideration. Its density, however, ordinarily will defeat good engagement unless special means are provided to introduce an element of greater or less flexibility in the design of the clutch.

The woven type of facing, as the name implies, is the product of a loom. Long-fiber asbestos mixed with a small percentage of cotton is twisted around a brass or copper wire to form a thread. The thread is woven into a straight band of the proper width but thicker than the finished product. The band is next cut to length, bent edgewise around a mandrel, the diameter of which corresponds to the inside diameter of the facing and stapled. The subsequent operations of impregnation, curing, drilling and grinding are similar to those for the molded type. To increase the density of the facing, it is subjected to an hydraulic-compression operation or is run between rolls under high pressure. An analysis of a representative facing of this type showed, by weight, 50 per cent of pure asbestos fiber, 25 per cent of wire, 10 per cent of cotton, and 15 per cent of other components. The necessary cotton content in the woven facing requires that the temperature in the curing operation be held below the charring point of cotton, to prevent burning the cotton out of the facing while the curing process is going on.

Comparison of Molded and Woven Facing

In comparing the woven facing with the ideal specifications we find that, so far as engaging qualities are concerned, it possesses an inherent yieldability under pressure and can be ground to reasonably close limits of parallelism, thus fulfilling both requirements. Regarding the requirements for hard service, the yieldability, which is an advantage in engagement, is a decided disadvantage from the standpoint of service, inasmuch as it introduces the necessity of adjustment in the clutch design. This condition is particularly true when the facings are first put into service and are taking their initial compression.

The coefficient of friction of a woven facing can be made to be mainly satisfactory although, when the facing wears to a point where the wire interweave becomes exposed, it is our experience that the coefficient of friction drops to a certain extent. The high-temperature characteristic of the woven facing is probably its weakest feature. The cotton content of the thread used in its manufacture will only withstand a limited temperature before charring. This temperature is decidedly below that obtained in severe clutch operation and results in burning the cotton out. The long-fiber-asbestos stock necessary in the fabrication of this kind of facing, together with the brass or copper-wire interweave, makes the finished price of the woven facing from 20 to 25 per cent higher than that of the molded type. The comparison of the characteristics of the two kinds of facing thus shows them to be about equal as regards the coefficient of friction and permeation. The woven type has an advantage from the standpoint of engagement, and the molded type has a decided advantage in its high heat-resisting ability and its lower cost.

One method of testing molded friction-facings is known as the "rebound" or "barrier" test. The apparatus consists of an inclined plate carrying at its upper end a narrow V-shaped metal guide or trough. A heavy, cast-iron plate provided with an adjustable barrier completes the apparatus. In use, the facings to be tested are placed singly in the guide, against the upper stop. They are then allowed to run down the incline, where they strike the cast-iron bed. The barrier is placed experimentally at such a distance and height that a dense perfect facing will clear the barrier on its rebound. Imperfect facings, either from lack of density, undercuring or checks in the rivet hole, will be lacking in resiliency and will not clear the barrier. We have found this method to be a very rapid and accurate way of testing

facings for defects that, otherwise, might be very difficult to detect.

Engagement Methods

One of the most interesting developments of clutch design in recent years is that by means of which the dense molded-type of facing can be used and a good quality of engagement still be obtained. This is particularly true as it applies to single-plate design. Probably the one great difficulty in the design of a single-plate clutch is to assure easy engagement or pick-up without chatter. It is our experience that this can be accomplished only by providing a certain amount of yieldability in the driven-member unit. Absolute parallelism of the driven member and facings reduces the necessity for yieldability, but does not obviate it entirely.

Two methods of obtaining yieldability exist. The first is to use a rigid plane-driven disc and woven friction-facings. The facings themselves, due to the woven construction and inherent resiliency, provide a limited amount of yieldability in engagement which helps materially to reduce the effect of chatter. Unfortunately, wear of the facing lessens this yieldability, due to reduced thickness and increased density caused by the continual spring pressure. Therefore, the engaging action of this design is smoothest initially and gradually becomes poorer. The second method is to use a very dense facing of the molded type and to provide for the necessary yieldability in the design of the driven disc itself. This method is being used commercially to our knowledge by three companies at present.

The driven disc used by the Durant Company is shown in Fig. 1. The outer rim-section of this disc is dished into a wave form and segmental sections of molded friction-facings are riveted to the crest of each wave on both sides of the disc. This construction disposes the facings alternately with respect to each other. In engagement, the reaction to pressure on any one segment is provided by the two adjacent segments on the opposite side. This results in a stress being set up in the rim section of the disc and in a deformation from its original wave form, the amount of deformation depending upon the amount of pressure exerted. It will be seen that an element of yieldability is thus provided in the metal disc itself, independently of the facings.

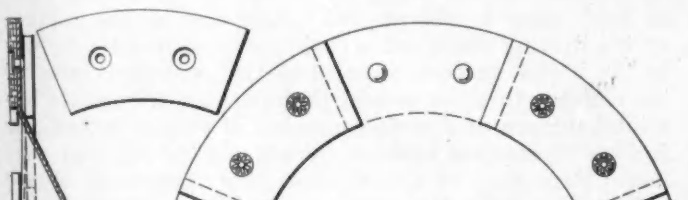

Fig. 1—One Type of Driven Disc

The Outer Rim-Section Is Dished Into a Wave Form and Segmental Sections of Molded Friction-Facings Are Riveted to the Crest of Each Wave on Both Sides of the Disc. This Construction Disposes the Facings Alternately with Respect to Each Other. In Engagement, the Reaction to Pressure on Any One Segment Is Provided by the Two Adjacent Segments on the Opposite Side. This Results in a Stress Being Set Up in the Rim Section of the Disc and in a Deformation from Its Original Wave Form, the Amount of Deformation Depending Upon the Amount of Pressure Exerted. Thus, an Element of Yieldability Is Provided in the Metal Disc Itself, Independently of the Facings

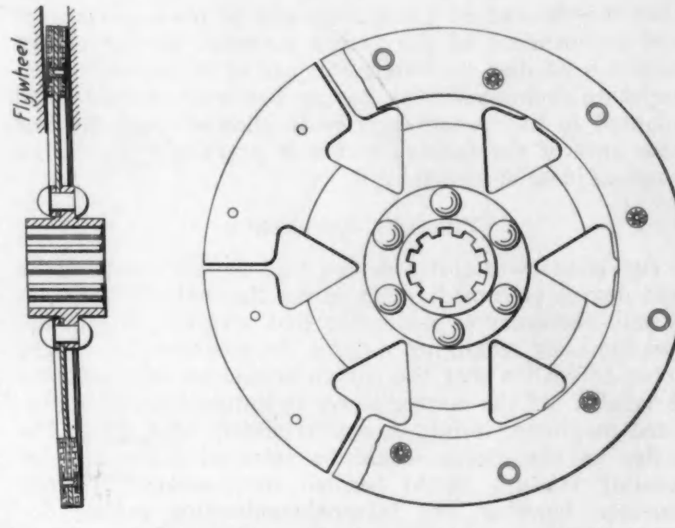

Fig. 2—Another Type of Driven Disc

In the Construction a Sheet-Metal Disc Made of High-Carbon Spring Steel Is Made into a Spoked Form, the Spokes Having Enlarged Facings Carrying Areas at Their Outer Ends. The Central Portion of the Disc Is Made Flat, but the Rim Section Is Formed into a 3-Deg. Cone. The Disc in This Form Is Heat-Treated To Give It a Spring Temper, Which Permits the Individual Spokes To Be Sprung Materially from Their Original Shape. The Facings, Which Are Ground to a Close Limit of Parallelism, Are Riveted to the Rim Section of the Disc and Thus Are Made To Conform to the Conical Portion of the Disc. In Engagement, the Inner Portion of the Forward Facing First Engages the Flywheel, While the Outer Section of the Rear Facing Engages the Pressure Plate. As the Engaging Pressure Is Increased, Deformation of the Individual Spokes of the Disc Occurs, and This Provides the Yieldability Necessary for Smooth Engagement

A similar method of this type, used by the Long Mfg. Co., is shown in Fig. 2. In the construction a sheet-metal disc, made of high-carbon spring-steel, is made into a spoked form, the spokes having enlarged facings carrying areas at their outer ends. The central portion of the disc is made flat, but the rim section is formed into a 3-deg. cone. The disc in this form is heat-treated to give it a spring temper that permits the individual spokes to be sprung materially from their original shape. The facings, which are ground to a close limit of parallelism, are riveted to the rim section of the disc and thus are made to conform to the conical portion of the disc. In engagement, the inner portion of the forward facing first engages the flywheel, while the outer section of the rear facing engages the pressure plate. As the engaging pressure is increased, deformation of the individual spokes of the disc occurs, and this provides the yieldability necessary for smooth engagement. Both of the foregoing methods are employed on single-plate designs.

The Fuller Company is using a similar construction in its multiple-disc dry-plate clutch. In the design, the molded-type friction-facings are riveted to the driving discs, which are made flat. The annular driven-discs of high-carbon steel are given a wave form that permits the wave crests to engage the friction facings first and gradually to deform as the pressure is increased. The deformation of the driven discs again provides for the necessary element of yieldability to assure smooth engagement.

Among the advantages claimed for these methods are

that the element of yieldability can be made permanent and independent of the facing material by the proper selection of disc material; the use of dense high-heat-resisting facing-material, having low wear-rate and well adapted to heavy-duty service is allowed; and the low wear-rate of the facings makes it practicable to design a non-adjustable clutch.

Thermal Efficiency

One element of clutch design that has not received its just degree of consideration is the thermal efficiency. It is only necessary to remember that a clutch, in pick-up, functions by changing engine horsepower into heat units, to realize that the design should be very efficient thermally. If the motive power in automotive work provided maximum torque at approximately zero speed, the duties of the clutch would be lessened materially or possibly its use would become unnecessary. Unfortunately, however, the internal-combustion engine depends upon speed to produce its torque and the clutch can only pick up its load smoothly through a period of slipping, during which time a varying proportion of the horsepower delivered is transferred into heat units that must be absorbed and dissipated by the clutch mechanism itself.

This consideration of thermal efficiency becomes more and more important as the severity of the clutch service increases. The recent increase in the use of motorbuses probably will do more to crystallize the realization of the necessity for thermal efficiency in a clutch than any other branch of automotive work. In a city-used motorbus, the severity of clutch duty is extreme. For mile after mile, in congested districts, the clutch is being used almost continuously and the heat absorption is very great. If the motorbus is to be successful, it must be able to operate under these severe conditions. Obviously, it is necessary to design the clutch to enable it to absorb and dissipate continuously a large number of heat units.

Problem of Thermal Efficiency

Our company has been doing a considerable amount of work on the problem of thermal efficiency in the last 4 years and, while we have made progress, we believe that much more remains to be done before our knowledge of the subject becomes sufficiently comprehensive to reach its full value to the industry. As a result of our work to date, we have reached the following conclusions:

(1) In a consideration of the thermal efficiency, the unit pressure of the facings is unimportant over a wide range of pressures. We have proved that facing failures result from conditions of high temperatures and that, if means are provided for absorption and dissipation of frictional heat, stepping up the unit pressures without injury to the facings is possible

(2) As a result of conclusion (1), it is our opinion that a single or two-plate clutch is the logical design for heavy-duty service. This is largely on account of structural considerations, it being much easier to provide for the necessary masses of absorption metal in a single or two-plate design than in a multiple-disc type

(3) The masses of absorption metal should be carried as a part of the flywheel weight. This necessitates that the facings be attached to the driven discs and, although the weight of the facings adds to the inertia of the driven member, the discs can be made very light and the total inertia of the driven member assembly kept low

(4) Cast iron is the best metal to use as a friction surface for engaging the facing. The free graphitic content of cast iron provides a slight lubricating effect and permits the surfaces to attain a smooth high polish. If steel engaging discs are used in a heavy-duty clutch, they should have a high carbon-content or preferably be heat-treated to a surface hardness that will not scuff. A low carbon-steel will scuff; that is, steel fibers will be pulled off of its surface in operation. These fibers become imbedded in the softer facing material and act as an abrasive to roughen the surface of the steel disc further. In providing the necessary weight for heat absorption, cast iron becomes the easiest to handle in manufacturing processes and is the cheapest

(5) At present, we provide two elements for increasing the thermal efficiency of the clutch. A very considerable mass of metal is provided in the driving discs. This is in reality a reservoir into which can be thrown a large quantity of heat units without raising the temperature of the driving disc too quickly. Such a disc is shown in cross-section in Fig. 3. In this consideration of the thermal efficiency, the center drive-plate in this two-plate design—in which three driving surfaces are provided; the flywheel, the center drive-plate and the outer drive-plate—has to do the largest share of the work and this should be borne in mind as an aid in understanding the arguments for thermal efficiency. It will be noted that the metal disc is made to extend outwardly and inwardly beyond the actual zone of the facing. This accomplishes two things, an increased mass and a larger exposed area for surface radiation.

Extending the driving disc in both directions from the zone of the facing has a distinct purpose. It provides a double path, outwardly and inwardly, for the conduction of heat from the facing zone. This is important, as the temperature of the engaging surface of the facing must be kept below a critical peak. The ratio of the surface of the driving discs not actually covered by the facings to the entire surface constitutes the radiation ratio of the clutch. In other words, if the center drive-plate has a total surface of a certain number of square inches, the facings themselves cover a certain portion of that surface. Expressed as a percentage, the number of square inches covered by the facing might be termed the "coverage ratio." As the severity of clutch duty increases, it is essential that this radiation ratio increase, since this is in reality a measure of how many heat units can be disposed of continuously by the clutch without unduly raising the surface temperature of the facings.

As an aid to radiation, we recommend for heavy-duty service that openings be made in the sides of the bell housing and at least one near the periphery of the flywheel to secure the advantage of the fan action of the revolving clutch and flywheel. A considerable volume of air can thus be drawn through the bell housing at ordinary engine speeds, which materially aids in surface cooling. This system has the disadvantage of allowing dust to enter the bell housing through the fan action. However, for heavy-duty service, the throw-out bearing should be housed and the dust will do no harm to the remainder of the mechanism. We believe the advantages of the system far outweight this disadvantage.

The clutch shown in Fig. 3 is designed especially for motorbus service and is capable of being used with an engine that develops 4500 lb-in. of torque. To give a more concrete idea of sizes, weights and areas involved in this particular clutch, the center and outer driving

disc weigh more than 32 lb. These two members absorb 75 per cent of the heat units liberated; the other 25 per cent is absorbed directly by the flywheel.

One of the advantages of the single or two-plate types from the thermal standpoint lies in the fact that the flywheel itself constitutes a driving disc and absorbs directly 50 per cent of the liberated heat in the single-plate type and 25 per cent in the two-plate type. The flywheel is an ideal member for this purpose, as it embodies a large mass of metal for heat absorption and presents large areas for surface radiation.

Regarding surface radiation, the center drive-plate of the design shown presents the greatest problem, inasmuch as it must handle 50 per cent of the frictional heat. In this design, the facings cover 47 per cent of the center drive-plate surfaces, leaving 53 per cent as a radiation ratio. This ratio is very high as present clutch designs stand, but further experience in heavy-duty work may demand that it be increased materially. The radiation ratio of the flywheel and of the rear driving-plate, each of which must handle 25 per cent of the heat, is much higher than that of the center drive-plate and provides an additional factor of safety. The application of the principles of thermal efficiency in the foregoing text has been directed to clutch designs for heavy-duty service.

Passenger-Car-Clutch Design

It has been our experience that a very satisfactory passenger-car clutch can be made in a single-plate design. If care is exercised in the design of the flywheel and a heavy cast-iron pressure-plate is provided, the thermal requirements can be well taken care of. We believe it is not good practice to house the clutch in the flywheel completely. Openings should be provided to allow air circulation through the clutch mechanism. A method for air circulation is shown in a single-plate de-

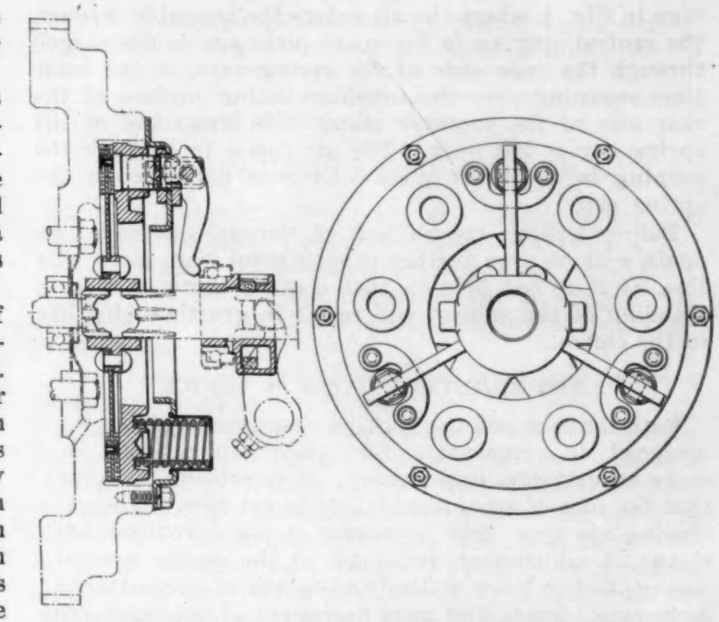

Fig. 4—Method of Air Circulation for a Single-Plate Design
In This Method, the Air Enters the Assembly through the Central Opening in the Cover Plate and Is Discharged through the Open Ends of the Spring Cups, at the Same Time Sweeping over the Rough Radiating Surface of the Rear Side of the Pressure Plate. The Outer End of the Spring Cup Is Left Open

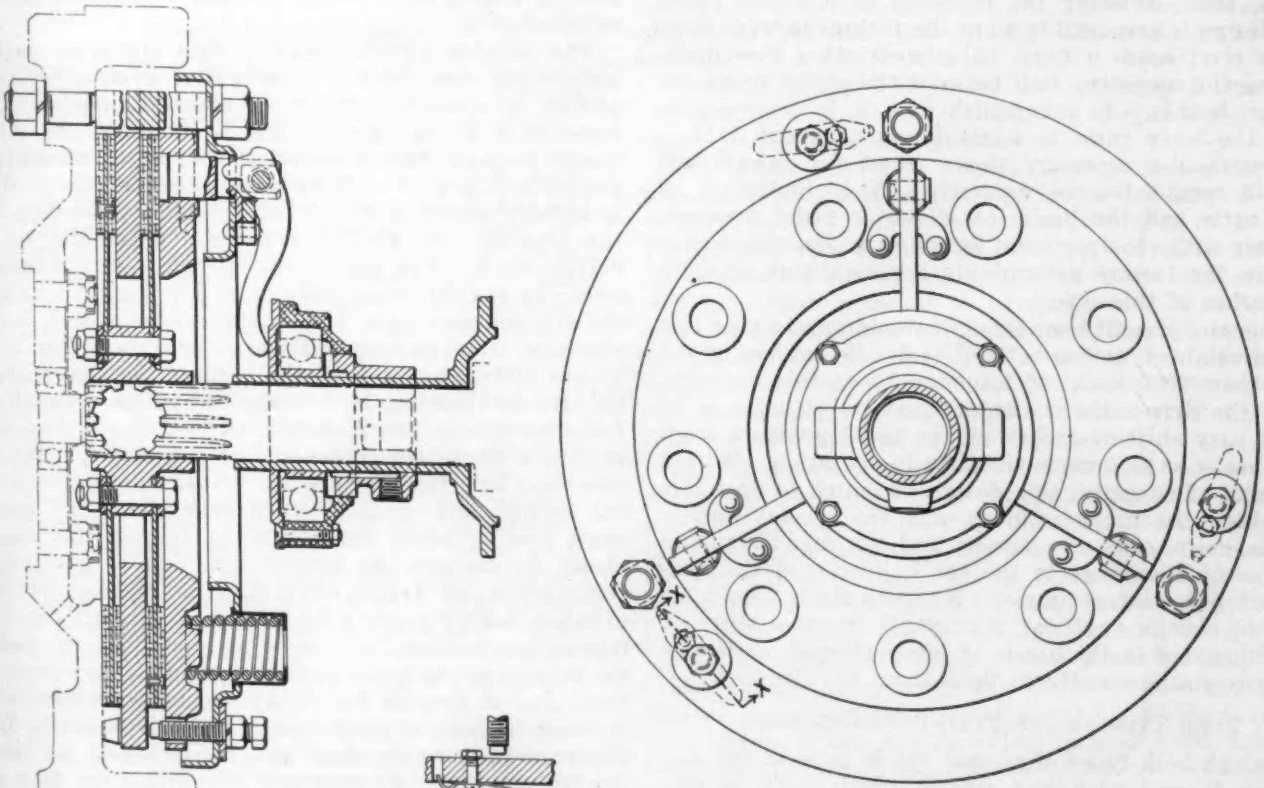

Fig. 3—Elements for Increasing Clutch Thermal-Efficiency
A Very Considerable Mass of Metal Is Provided in the Driving Discs. This Is in Reality a Reservoir into Which Can Be Thrown a Large Quantity of Heat Units Without Raising the Temperature of the Driving Disc Too Quickly. The Metal Disc Is Made To Extend Outwardly and Inwardly beyond the Actual Zone of the Facing. This Accomplishes Two Things, an Increased Mass and a Larger Exposed Area for Surface Radiation. The Clutch Shown Is Designed Especially for Motorbus Service and Is Capable of Being Used with an Engine That Develops 4500 Lb-In. of Torque

sign in Fig. 4, where the air enters the assembly through the central opening in the cover plate and is discharged through the open ends of the spring cups, at the same time sweeping over the rough radiating surface of the rear side of the pressure plate. The outer end of the spring cup is left open. The air comes in through the opening in the cover plate, and goes out through the spring cup.

Before leaving the subject of thermal efficiency, we again wish to urge further experimental work along this line, as it is our opinion that a more thorough understanding of the subject will result in greatly added life in the clutch.

Non-Adjustable Types of Clutch

Both the cone and the multiple-disc type of clutch were designed to compensate for wear automatically and make adjustments unnecessary. It is evident, therefore, that the idea of non-adjustability is not new. When the single-plate type first appeared, it was provided with means of adjustment, inasmuch as the spring pressure was applied to lever multiplying-means of comparatively large ratio, demanding more movement at the inner ends of the levers than could be accommodated without adjustment. This practice was followed for many years in practically all designs of this type. It was not until recently that non-adjustable, single-plate clutches made their appearance.

The non-adjustable type of single-plate clutch, like all designs, has its advantages and limitations. It is made possible by the development of friction facings having a very low wear-rate and improvements in driven discs, whereby the inertia of the driven member is held to low limits, thus obviating the necessity of a clutch brake. The design is arranged to allow the facings to wear down to the rivet heads without adjustment other than maintaining the necessary lash between the clutch pedal and the toe boards. To accomplish this, it is necessary to limit the lever ratio to a maximum of about 5 to 1. Otherwise, the necessary sleeve travel for release and wear-in would become excessive. This limitation of lever ratio and the limits of allowable pedal pressure, together with constructional limits of driven-disc diameter, are the factors determining the maximum capacity of clutches of this type.

From our present knowledge, it would appear that this non-adjustable type can be built to handle engines of not more than 2000 lb-in. of torque. Above this capacity, either the driven-disc diameter must be so large as to defeat easy shifting-ability or the pedal pressure must be so heavy as to become tiresome in operation. Within its limits of capacity, this design of clutch is desirable from both the manufacturing and the service angles. Its simplicity, ease of assembly and low manufacturing cost are of advantage to the car builder, and the non-adjustability feature makes it particularly desirable from the service angle, as it prevents the possibility of mal-adjustment in the hands of inexperienced mechanics in service-stations scattered throughout the Country.

Push-Type versus Pull-Type Control

Although both types of control are in general use, the tendency toward push-type control, particularly in single-plate designs, is general. The push-type control appears to offer several advantages. It is possible to build it more compactly and this will allow a shortening of the clutch bell-housing with less weight, less overhang of the transmission from the engine and a saving in cost.

In a clutch having push-type control, the clutch pedal-shaft is normally located below the clutch center-line. This permits the use of longer clutch and brake pedals, an advantage in both cases, but the principal advantage is that, when end-play develops in the crankshaft, the reaction of the releasing pressure causes the crankshaft to be pushed forward to the limit of its end-play and this automatically helps to establish a positive clearance between the front clutch-facing and the flywheel without making it necessary for the driven member to float back to obtain release. But with a clutch having pull-type control, this action is reversed and the crankshaft, on release, is pulled back through its limit of end-play into the forward facing, which must float back the additional distance of the amount of end-play to establish release.

Improvements in Release-Sleeve Designs

Mounting of the clutch-release bearing, together with the attendant problem of providing proper lubrication to both bearing and sleeve has always been one of the difficulties of clutch design. In the past, these members have been mounted, both slidably and rotatably, on the driven shaft with lubrication provided by hollow drilling the driven shaft and depending upon the transmission lubricant as a source of supply. Other designs have mounted the release sleeve on an extension projecting rearwardly from the cover plate of the clutch. This design has the advantage of mounting both bearing and sleeve independently of the shaft but, since the bearing and the sleeve are both rotating at flywheel speed, it is not an easy matter to provide lubrication. Usually, the hollow-shaft method of lubrication from the transmission is employed in this case and solves the problem satisfactorily.

The greatest improvement in this direction, particularly when used with a push-control design, is accomplished by extending the front transmission-cap in the form of a sleeve, upon which is mounted the release sleeve proper. One form of this type of mounting is shown in Fig. 4. It will be noted that the release sleeve is slidably mounted on the non-rotatable extension from the transmission and is entirely independent of the driven shaft. The sleeve can be held against rotation either by the throw-out yoke or by a pin extending from the transmission case. Since the release sleeve is non-rotatable it is an easy matter to provide either oil or grease lubrication to both the bore of the sleeve and to the release bearing by a tube extending through the floor-boards. In this particular design, the control shaft is located above the center-line of the clutch, making it necessary to bring the tube for grease lubrication out at the bottom and around. Ordinarily, with the control shaft coming below the clutch center-line, this can be placed on top and the flexible tube can be run out directly above; or, for oil lubrication, an oil-reservoir type of sleeve having a drip tube coming up through the floor-boards can be installed. It is also possible, by placing the oil seal at the extreme front end of the transmission extension, to provide for direct transmission-lubrication without the necessity for drilling the driven shaft. With clearance between the shaft and the inside of the sleeve, the transmission lubricant has free access up to a certain point and can be taken off at any point for lubricating either the sleeve or the bearing. A 1/8-in. hole on the side of rotation, from 45 to 90 deg. up, differing with the type of transmission used, is sufficient to provide lubrication. This design has been used by at least one of the large companies for the last 18 months and, since

it appears to solve many of the difficulties in the lubrication of these parts, we believe it will be adopted widely by the industry in the not far distant future.

Balancing and Its Effect Upon Design

The efforts of motor-car builders to reduce vibration periods is making the balancing of clutch units a necessity. A 20-lb. clutch will produce an unbalance of 0.320 in-oz. for each 0.001 in. of eccentricity of its center of gravity. It hardly seems justifiable for a manufacturer to go to the trouble and expense of carefully balancing the crankshaft and flywheel, only to hang an unbalanced clutch upon the flywheel in assembly. On account of the short longitudinal over-all dimension of most clutches, static balancing should prove satisfactory. However, with the balancing machines available, it is about as easy and inexpensive to balance the clutch dynamically.

The matter of balancing is bound to have its effect upon clutch and flywheel design. In producing the flywheel, it will be necessary to maintain close limits of the pilot diameter for mounting the clutch, as well as close limits of eccentricity of the same pilot. The mating clutch-unit must also be held closely to size. One of the more serious phases of the situation lies in the fact that adjustment of the clutch may mean an angular rotation of some of the members of the clutch assembly which may cause an unbalance, even though the unit were perfectly balanced in its initial assembly. This new demand on clutches is an argument for adjusting means that do not disturb the angular arrangement of the various parts of the assembly, and is also an argument in favor of the non-adjustable type where the parts are always in the same angular relation regardless of the conditions of wear on the facings.

Future Possibilities

A forecast of what the future may hold in the way of clutch improvements is at best a surmise, but some features of the following prophecy may be realized:

(1) An increasing use of single-plate clutches is likely to occur because of simplicity of design as well as lower manufacturing costs. This should be accompanied by improvements in the present designs from both the standpoint of operation and that of durability. A suggestion along this line is for a friction facing capable of high heat-resistance, the coefficient of friction of which is greatly in excess of that of existing types. This would permit either smaller clutches for the same capacity or lower pedal-pressures for existing sizes, and would extend the field of the single-plate type of clutch to larger engines, the present field being limited by two considerations; the inertia of the driven disc, which governs easy shifting ability, and spring pressure as measured at the clutch pedal

(2) The development of a single-plate design that obviates the necessity of a sliding spline fit between the clutch hub and the driven shaft. This would eliminate one of the chances for backlash in the driving system and would be very desirable

(3) The development of some simple vibration-damping means between the engine and the driving system. This improvement is under way at present, but in its present state it presents constructional difficulties in manufacture and adds considerably to the cost

(4) The clutch throw-out bearing has generally been of cheap design and the means of providing lubrication have been inadequate in many cases. Considerable experimental work is being done in attempting to replace this bearing with a self-lubricating block of compressed graphite, engaging a steel or a cast-iron washer. Work along this line should be encouraged as surprisingly good results may be attained

THE DISCUSSION AT CLEVELAND

C. N. Thompson:—What are the minimum and the maximum foot-pedal pressures desirable at present?

E. E. Wemp:—The clutch pedal-pressure should not be less than 20 lb.; the maximum for passenger cars should be 28 lb. Desirable pedal pressure averages between 22 and 25 lb.

Question:—Will end-play in the crankshaft cause a rattle or a knock in the clutch?

Mr. Wemp:—I would not expect a knock to develop in the clutch itself. Excessive end-play in the crankshaft always makes itself known by its own distinctive noise. In the push-type control, particularly with the use of a flexible disc, the crankshaft, on release, due to the reaction of the thrusting pressure of the release, is pushed forward. That will not push the driven member on the driven shaft because, at the time the push starts, it is under a full torque load and, as the crankshaft is pushed forward, that action occurs before releasing occurs. Then, when the release occurs, the pressure plate is positively drawn back out of engagement and the crankshaft is pushed forward so that, actually, the driven member does not have to move at all. That is the condition on a push-type control and one of its chief advantages. In the pull-type control, the condition is just the opposite. The reaction to the releasing pressure draws the crankshaft back into the facings and the facings have to float back, not only their normal amount of release but that amount plus the end-play of the crankshaft.

John Younger:—What are the merits of Ferodo on clutch linings as used in England, as compared with the clutch linings used in this Country?

Mr. Wemp:—I have Ferodo facings under test at present. The characteristics, so far as one can tell outwardly, are very similar to the molded type of facing. Ferodo is a very dense type of facing. I think that is the one reason for its successful use in the applications that have been made of it. I understand that practically all the clutches in the London General Omnibus Co. vehicles are provided with Ferodo facings. However, in this Country, the price stands against them because they are decidedly higher in price than the type of facing that can be purchased in the United States.

Question:—Mr. Wemp alluded to unit pressure in regard to the design of a clutch, saying that it made less difference than some have thought. What pressures illustrate good practice, both maximum and minimum? He also intimated that a higher coefficient of friction is desirable and that he looks for some development in that line. What coefficient of friction is he aiming at or hoping for, along with the coefficients now existing?

Mr. Wemp:—Regarding the allowable unit pressures on facings, I qualified my statements by saying that the unit pressures are not important provided the thermal requirements are taken care of. With the thermal requirements taken care of, we have used unit pressures as high as 55 lb. per sq. in. I believe that is nowhere near the limit of the pressure that can be used successfully. When time permits, I shall run the pressures up around 150 lb. per sq. in., and I expect to get good results. However, the pressures on the large clutch for motorbus service, are held to about 25 lb. per sq. in. The

normal pressures in passenger-car-clutch designs run from between 40 and 45 lb. per sq. in., and very excellent service is obtained from the facings.

We have had numerous instances in which a clutch has been in operation for at least 60,000 miles and in which the trademark of the facing maker was still perfectly legible on the facing. As another specific instance, a taxicab clutch working in the Loop District of Chicago showed a total combined wear on two facings of approximately 0.012 in., or only 0.006 in. wear per facing after 45,000 miles.

The real coefficient of friction is determined by laboratory tests. A good facing should show a coefficient of friction of 0.30 or better, and it may run up as high as 0.35. But when the facings are installed in a clutch and the apparent coefficient of friction of the facing is taken from the dynamometer reading, another result is obtained because the many frictional elements of the clutch design detract from the real coefficient of friction and make the apparent coefficient of friction very much lower. This apparent drop in the coefficient of friction is a function of the clutch design. It is least in the single-plate clutch and becomes more pronounced as the number of driving plates increases. For example, in a multiple-disc clutch, as one starts to engage the clutch and to pick up a torque load, all the slidable driving plates must slide on their pins under a torque load and the frictional coefficient of the driving discs themselves, sliding upon their pins, detracts from it; this does not detract from the real coefficient of friction of the facing, but the apparent coefficient of friction becomes smaller. For example, we always allow at least from 0.20 to 0.25 in figuring the capacity of the clutch of a single-plate or a two-plate design. In multiple-disc design, where the number of facings becomes large, it has been my experience that the value of the coefficient of friction must be dropped to about 0.12 or 0.15, not because the coefficient of friction of the facing is any different, but because the collective efficiency of the clutch becomes less as the number of plates increases.

A MEMBER:—I was under the impression that the coefficient of friction of these clutch discs was approximately the same as that of brake linings, but it must be lower according to the figures that you have given.

MR. WEMP:—It is lower. Differences exist in the impregnating compound used, in the brake material, in the clutch material, and in the clutch facings. Impregnating solutions used in clutch facings range from mineral salts and glutinous compounds down through the creosote or asphaltum-base compounds. Under high temperature, the impregnating solution must not bleed out of the facing. This is largely determined by how high a temperature the furnace attains when the facing is cured, as well as by the nature of the impregnating compounds.

The asphaltum-base impregnating-compounds work out best from the standpoint of not bleeding at high temperature. The molded type of facing has practically a pure asbestos base and nothing in the nature of the facing exists but what can withstand a very high temperature; the particular molded facing we are using is cured at a temperature of 650 deg. fahr. Woven facings must be kept below that temperature, the charring point of cotton being about 470 deg. fahr. Curing temperature has a wide range, and a much better chance exists to carbonize the impregnating compound which, if it is not carbonized, will show later in the form of bleeding when the temperature reaches the higher stages that it is bound to reach in clutch operation. In many cases, the temperature of the clutch itself after a bad period of slipping will be more than 650 deg. fahr. The color of the clutch plates proves that it has reached 650 deg. fahr. at least.

A good impregnating compound should not be hydroscopic. Any of the mineral salts or any of the glucose compounds are hydroscopic. The way in which this shows is when cars are put in storage or are operated in sections of the Country where the degree of humidity is high, and particularly near the sea coast, where the action of salt air is operative, the hydroscopic property of the impregnating compound will attract water to the facing and the clutch will freeze up. Due to this cause, I have seen clutches frozen so hard that it was necessary to break them apart with a hammer. That condition does not exist in good asphaltum-base impregnating-compounds because oil and water do not mix.

CHAIRMAN CLYDE S. PELTON:—Would it improve or aid in clutch performance if the engine performance were improved to such an extent that much higher torque at low engine-speed could be obtained? It would not be necessary to race the engine to produce the necessary torque, and the clutch would need to absorb less power or heat to take up the load.

MR. WEMP:—It would help very materially. The internal-combustion engine depends upon speed for its torque and, if one could make the internal-combustion engine approximate the steam engine, in which the torque is the maximum at practically zero speeds, the clutch would not be necessary. However, any improvement in engines that will step-up the torque at lower speeds will add materially to the life of the clutch because it will reduce the period of slipping and this is the period that wears the clutch out the fastest.

CHAIRMAN PELTON:—I doubt that internal-combustion engines ever will be brought to a point of approximating steam-engine performance, but I know of research work under way at present in which an engine developed 160 lb-ft. of torque at 200 r.p.m. and 170 lb-ft. at 500 r.p.m., which was the maximum torque; and the torque curve was approximately horizontal from 200 to 1800 r.p.m. and then dropped off gradually.

MR. YOUNGER:—Do people "ride" the clutch as much as they used to do?

MR. WEMP:—A decided improvement has been made in that respect. No excuse exists for riding a clutch pedal. A good driver should de-clutch the very last thing in bringing his car to a stop. In other words, the engine is one of the best brakes so long as it is used up to the point of stalling the engine and so long as the right foot, which normally is on the accelerator, has to be lifted from the accelerator pedal, put upon the brake pedal and held there an instant before bringing the speed of the vehicle down to the point where the engine is apt to stall; one has all that time to raise the left foot off the floor to put it up on the clutch pedal.

QUESTION:—What is the average difference between the coefficient of friction of rest and that of motion for clutch facings?

MR. WEMP:—We have not investigated that phase of the subject because a clutch, to be successful, must hold the engine under conditions of friction of motion. Our method of testing a clutch for capacity is to speed the engine with the clutch disengaged and then to let the clutch in; it must then kill the engine through a very short period of slippage to be considered a clutch of sufficient capacity for the engine. The coefficient of rest is probably 25 to 30 per cent greater than the coefficient of friction of motion. The cone clutch of former days

justifies our theory of thermal efficiency for present clutches. In the old cone-clutch design, the female member of the cone out at the rim of the flywheel had a leather facing attached to the driven member. If one considers how much heat leather will withstand before it chars, I think that the only reason the cone clutch did stand up was because it was almost an ideal design from the standpoint of thermal efficiency. The frictional heat was created between the outer surface of the leather and the inside surface of the flywheel. The leather, fortunately, is not so good a conductor of heat as cast iron, and a large percentage of the heat flowed directly into the flywheel. The flywheel had a large mass that absorbed a great number of heat units without raising the temperature and, revolving as it did, provided excellent opportunity for dissipating heat. The basis of our experimental work on thermal efficiency for plate clutches has its origin in knowledge of the cone-clutch design.

W. E. ENGLAND:—A driver should not "ride" the clutch pedal; but, in actual operation, many do so. We put a 15-lb. spring on the clutch pedal to keep it away from the throw-out bearing.

MR. WEMP:—We recommend the use of the return spring to keep the throw-out bearing thrown back. We know that many people "ride" the clutch pedal, although I believe that in proportion the number has decreased in the last few years. It is very largely an educational problem; people learn to use the clutch last instead of first. Eventually, it will be possible to lighten clutch-pedal pressures. We think now that clutch-pedal pressure should not be low enough so that the weight of the foot will cause clutch slippage; if the pressure drops below 20 lb., slippage will occur.

QUESTION:—To what extent has the single-disc clutch displaced the multiple-disc clutch in the automobile?

MR. WEMP:—The types of clutch used in the leading cars of today indicate that the percentage of single or two-plate clutches has increased very materially. I know of only one "production" car in the United States now that is using the cone clutch, and I believe that will be discarded very soon. Practically all the newer designs use the single or the two-plate clutch.

L. C. HILL:—Does any possibility exist of developing a means of starting cars without a three-shift transmission by deliberately making a slipping clutch the medium for starting and providing some means of cooling it?

MR. WEMP:—I believe that it is not practicable to make the clutch take the place of the transmission, which is what that would amount to. For city driving, where one is not apt to get into a hole, that might be possible. In city driving, very few people use low speed. They start on second speed, which is perfectly permissible with a good design of clutch. But I believe it would not be practicable or possible to make a clutch that would withstand country driving and absorb the necessary number of heat units continuously demanded by that kind of work. I have ridden in an experimental car equipped with a device such as Mr. Hill mentions. It is made by a company in Philadelphia and is in effect a centrifugal clutch built in behind the regular clutch. As the car is slowed down and the engine speed comes down to a predetermined point, the centrifugal weights that have been holding the clutch in engagement operate and the centrifugal action is counteracted by a series of springs so that the clutch slips. The idea is that one does not go out of gear but merely removes his foot from the accelerator. Increased engine-speed throws the centrifugal weights into action and after a period of slipping the clutch will start the car. That sort of service might be possible with a good design of clutch. The particular people who have been experimenting with the device have not taken care of the thermal requirements of the clutch to an adequate degree, and they have been forced to run the clutch in oil to dissipate the heat; but, for that kind of service, I believe a clutch can be built that will take care of it.

QUESTION:—Has any tendency to increase the diameter of the spline or the length of the spline been noticed?

MR. WEMP:—An increase in the diameter of the spline is good practice. The majority of designs have come to a $1\frac{1}{2}$-in. shaft-diameter and 10 splines. Ten splines constitute a great improvement over six splines, and a greater improvement over four splines. In a four-spline shaft, nothing is provided to hold the hub in place unless the bore of the hub is made to fit closely upon the roots of the spline and the shaft. With six splines or more, it is possible to make the hub fit only on the sides of the spline, which is the practice in either 6 or 10-spline construction. The diameter of the shaft, $1\frac{1}{2}$ in. for example, is very much in excess of what is necessary to transmit the torque, because only the engine torque is transmitted. It is in front of the transmission and the increase in size is merely to reduce the unit pressure in the spline. From the manufacturing standpoint, it is very bad practice to increase the length of the spline to much more than $1\frac{1}{2}$ in. because it is very difficult in producing either a high-carbon oil-treated spline or a carbonized spline to keep the teeth straight and have a uniform section throughout a long length. We make the spline $1\frac{1}{2}$ in. long, and hold a tolerance of 0.002 in. in spline width throughout the length. In going above that, it would be very difficult to maintain those tolerances. If any change were to be made in that practice, my recommendation would be to change the diameter and not the length.

MR. YOUNGER:—In the early days of the multiple-disc clutch, trouble due to drag was experienced. Some years ago, I used the multiple-disc idea in an attempt to design a brake, but the element of dragging made it unsuccessful. Have you been able to overcome that effect of drag so that a multiple-disc device could be used as a brake?

MR. WEMP:—A design similar to that used by the Fuller Company might be employed. The friction facings are attached to perfectly flat driving plates and the driven discs are made in a wave form. Any wave-form driven-disc will automatically free itself on release, while a flat plate does not always do so. In a single-plate-clutch design, particularly if grease is present as sometimes happens, the excess grease gets out on the flywheel face and consequently upon the facing because usually no means exists of holding the grease in the bearing. If the disc is flat, after the clutch has been heated up and the lighter part of the grease has been burned off, it leaves a sticky asphaltum base and the facing is very apt to stick and cause a drag upon release. With any type of a wave-form disc that condition does not occur because the wave-form disc will have enough breakaway pull to overcome the cohesion of the sticky material that is left upon the facings.

The thermal requirements of a brake probably would be in excess of the thermal requirements of a clutch, and it is difficult to make a design of multiple-disc clutch that provides a sufficient number of facings so as to take care of the thermal requirements without causing complications in the construction. That was one reason, after we decided upon the necessity for thermal effi-

ciency, that we also decided to hold it either to single-plate or to two-plate design.

MR. ENGLAND:—Of what material is the clutch spline made, what heat-treatment is given it and what degree of hardness is used?

MR. WEMP:—We use No. 1020 steel, from bar stock rather than a forging. We have found it almost impossible to hold a forging to within the required limit of 0.002-in. thickness. Our explanation of this is that the structure of the steel in a forging varies considerably. In the forging shop, they attempt to get as many pieces out of one heat as possible, and the structure of the first piece from the heat is entirely different from that of the last one, so that method was not successful. We made all of our hubs from bar stock of No. 1020 steel, and the pieces are heat-treated previously so as to reduce the material in size and give it a more severe shock before any machining operations are done than it will ever receive afterward. The inside of the spline is the only part of the finished hub that is left hard, the carbon being all turned off of the outside where, of course, it is unimportant; the hubs are carbonized in the regular way.

It is necessary to exercise considerable care in the packing of the pots to keep a uniform thickness of carbonizing material around the hubs; then, when they are given the final heat-treatment for hardness, they are quenched in a special compound to prevent the formation of scale. We hold to file hardness on the inside of the hub only. Tested with a scleroscope, the hardness does not show up as being very great, due to the fact that a very deep depth of carbonization cannot be obtained in the required width of teeth; but the file hardness represents a scleroscope hardness of about 70 if a sufficient body is back of it to give a true scleroscope reading.

MR. ENGLAND:—Do you finally broach the side before you carbonize and harden, or after carbonizing and then hardening after that?

MR. WEMP:—We broach first, then carbonize and re-broach; the re-broaching is merely a cleaning out, to take out what little distortion has been caused by the carbonizing process. Then, after the re-broaching, the hubs are finished from the spline itself, making the disc run through with the spline.

QUESTION:—What is the advantage of the spoke-type light driven-disc with reference to the possibility of the clutch being installed slightly out of line with the crank-shaft?

MR. WEMP:—We make the driven disc out of 0.80-per cent carbon stock, and the disc has six individual spokes. A disc having spokes has several advantages; it provides a very flexible disc so that misalignment of the transmission and the engine is taken care of more easily. Whatever that amount of misalignment happens to be, the driven disc must travel through that distance twice per revolution and, in 3 or 4 years of the life of a motor car, the number of reversals of stress becomes formidable. Another advantage of the spoke-driven member lies in the possibility of making the disc flat in production. With a high-carbon disc, if it is given an actual spring temper, that is, if it is heated beyond the critical temperature and quenched, the rim tension of the steel will cause the disc to buckle and, without the relief slots, it is almost impossible to make a flat disc without a peening operation, and that would not be very practicable. In the spoke form of disc, the spokes extend down to within a short distance of the center of the disc. The problem then is not one of trying to keep a disc say 8 in. in diameter flat, but it is to hold a ring flat that is about 3 in. outside and $1\frac{7}{8}$ in. inside diameter. The spoke sections will not create any more rim tension than as though one were attempting to flatten a flat piece of steel of that dimension. We have found it possible in production to hold a $7\frac{3}{4}$-in.-diameter disc flat within 0.005 in. without any serious difficulty.

THE DISCUSSION AT DETROIT

QUESTION:—Why is it necessary to make the discs so flat, if the last operation puts a kink in them?

E. E. WEMP:—In our design, the two-plate clutch spaces the two driven members to provide a natural clearance over the center driving-plate and, in engagement, the spoke members of the disc have to be bent inwardly to pick up the center driving-plate. In that design of clutch the plates are made perfectly flat. It is in the single-plate design of clutch, where it is not possible to get that method of step engagement, for that really is what it amounts to, that a kink is put in. After enough pressure has been applied to overcome the resistance of the spokes of the two driven discs, the two center facings pick up the center drive-plate. But with this method, for a single plate, the plate is coned from a certain portion outwardly. Naturally it is not drawn on a flat fixture. The cone is put into the top and the bottom pieces to produce the cone in the disc.

QUESTION:—Why put a vibration damper on the rear end of the engine when the load at the rear does the damping?

MR. WEMP:—Placing a vibration damper in the clutch provides a flexible connection between the engine and the mechanism behind the clutch. In other words, the propeller-shaft impulses in both directions, as they come from the rear, are not absorbed by or thrown directly into the solid mass of the inertia of the flywheel. This flexible means allows dissipating these impulses to a certain extent. The noise set up from the load on the rear comes from the necessary mechanical joints in both the clutch and the transmission, such as in the fit of the hub on the spline; also, it comes from the mating of the third-speed sliding-gear on the main transmission-shaft, and the third-speed sliding-gear on its own shaft. At least three joints must be able to slide and, therefore, they must have some clearance. The total clearance of the three may be sufficient to cause considerable noise.

L. K. SNELL:—What minimum running clearance is required to release a single-plate clutch? What effect has torsional whip or deflection of the propeller-shaft and the axle shaft on clutch chatter?

MR. WEMP:—It depends somewhat upon the design, and very largely upon how true the driven disc runs after it is assembled to the hub. A single-plate clutch of our design necessarily requires a greater amount of clearance than a flat driven-disc because of the conical section given the driven member, which partly flattens out in engagement. A 0.06 to 0.07-in. clearance will give perfectly free engagement, but we provide more.

QUESTION:—Can disc clutches, when dragging, be cleaned without removal and without damaging the facings? I refer to particles of the clutch discs that get down into the clutch itself.

MR. WEMP:—If oil gets on the surface of the clutch facing in any considerable quantity, it is almost impossible to wash it off. About the only way is to remove the facing and scrub it and, even then, one cannot get it off entirely. The washing process will dispose of the particles of friction facing that are worn off. Centrifugal force naturally tends to keep them out, although some of them do get in; but, to wash off oil, I think it would not be a satisfactory method.

CHAIRMAN W. R. STRICKLAND:—What is the best washing compound?

MR. WEMP:—We use kerosene. We have not tried anything else.

C. W. FLOSS:—Can oil be used with a molded facing? If so, what percentage of increase in pressure would be necessary?

MR. WEMP:—Oil can be used with a molded facing very successfully. A mixture of half motor oil and half kerosene, which is the usual mixture to take care of temperature conditions in winter, would require about a 30 per cent increase in spring pressure. Pure motor oil in the clutch requires about a 50 per cent increase.

R. E. PLIMPTON:—What is the best type of clutch for driving a motorbus in the city? Which type requires the most energy if engaged and disengaged frequently?

MR. WEMP:—The best type of clutch for such service is one that has the lowest amount of driven-member inertia with the best brake. For city motorbus service, practically all the large motorbus companies have adopted the single-plate type of clutch. This includes the London General Omnibus Co., the Fifth Avenue Coach Co., and others. Although they have to use very large single-plate clutches, the shifting characteristics of that clutch are not well represented by the majority of motorbuses because of the transmission location. On practically all, the transmission is located amidships and has a long forward propeller-shaft that gives considerably more inertia in the propeller-shaft than in the driven member of the clutch. From the standpoint of operation, a very much easier shifting job could be made with the same clutch, of the same diameter and weight of disc as that used in unit powerplant design.

BOYD W. EVANS:—Why not operate the clutch in oil and eliminate the problem of heat dissipation, bearing lubrication and rapid wear?

MR. WEMP:—At present, the disadvantage lies in the weather conditions for an oil-operated clutch in passenger-car use. At zero temperature a clutch running in oil may break loose and it may not. The dry-plate clutch has eliminated that difficulty entirely. However, the problems of lubrication have been introduced, and have been rather difficult to solve. More trouble with clutch throwout-bearings has been experienced than with any other particular bearing in the car. It usually is a cheap type of thrust bearing, and it is difficult to get oil to it. If means are provided and they are external means, in many cases the owner neglects to do the oiling through the means provided. A considerable amount of work is being done on replacing the throwout bearing with a block of graphite.

CHAIRMAN STRICKLAND:—Have you had any experience with other types of bearing than the thrust type?

MR. WEMP:—The annual-contact type, which has both radial and thrust capacity, is a better type; but the cost is decidedly greater.

W. M. SMITH:—What is the usual spring pressure required in proportion to area of clutch facings in a single-plate design?

MR. WEMP:—When the facings are of ordinary width, the facing area does not enter into the calculations. It is purely a question of mean radius of the facing, the number of facings and the spring pressure needed to hold the given torque load. The area of the facing naturally governs the pressure per square inch; however, we believe that pressure per square inch is not a very important consideration, particularly if a clutch is made thermally correct. Some of the old multiple-disc clutches having a unit pressure of 7 lb. per sq. in. may not last any longer than those that have a unit pressure of 45 lb. per sq. in.

L. P. KALB:—How many inch-ounces of unbalance are permitted in the clutches made by your company?

MR. WEMP:—The closest balance we have made any effort to obtain is 0.5 in-oz., which is, we believe, considerably closer than the usual requirements, these being more nearly around 2.0 to 2.5 in-oz.

G. L. MCCAIN:—What is your opinion of "one-way" driving-lugs on splines or flywheel engagement with plates? Sometimes, in forming the driving lugs on the plate, the pressure side has been favored, and sometimes the other side has been left off entirely or used simply for locating.

MR. WEMP:—While more wear exists on the driving side of the plate, apparently for a considerable part of the time, probably during coasting conditions, the drive is on the opposite side of the plate. It has been our practice to provide equal service on both sides, not trying to favor the driving side.

R. A. WEINHARDT:—Is the hub of the driven disc heat-treated or hardened? If so, what material is used and how is it hardened?

MR. WEMP:—It is our usual practice to make hubs of No. 1020 stock steel carbonized on the inside and splined only, the carbon being turned off of the outside after the carbonizing operation. It is hardened to a scleroscope hardness of approximately 70.

QUESTION:—How do metal and fabric universal-joints compare regarding their effect on clutch noises?

MR. WEMP:—That is a difficult question to answer because the propeller-shaft is only part of the transmission unit. I have had experience both ways with it; in some cases the fabric joint apparently made the noises greater and in other cases it seemed to soften them. In dealing with so-called clutch noises, it is really a combination proposition clear from the engine back to the rear wheels, and it is hard to segregate noise to one unit.

JOHN MCGEORGE:—Referring to the quality of the thrust bearing, could not some of the trouble be stopped by using a better type of bearing than is commonly used?

MR. WEMP:—Yes.

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Coordinating Gear Design and Production Methods

By PERRY L. TENNEY[1]

PRODUCTION MEETING PAPER

ABSTRACT

PERIODICALLY recurring problems of gear noise and wear which seem to arise from no specific cause frequently affect the manufacturing side of the automotive industry and especially the gear-manufacturers. While much has been written and discussed about the mathematics and geometry of gears, which should overcome all of these problems, the trouble unfortunately still persists. The paper outlines the experience of the organization with which the author is connected in solving a rather difficult problem that offered an opportunity for a more thorough analysis than did its predecessors. Laboratory and dynamometer analyses of the product showed that it compared favorably with the output of other factories. Throughout the entire preliminary investigation evidence was found that the coordination of the high points found in each steel as furnished by the mill, its heat-treatment, the details of the tooth form, the mathematics of gear action and the manufacturing processes would enable great strides to be made in both increasing the performance and reducing the cost of the product.

The first point attacked was the steel, which was a No. 5150 S.A.E. Steel that had been substituted some years before for the chrome-vanadium No. 6145 steel originally used. A series of tests was made on practically the entire group of chrome-carbon, chrome-vanadium, chrome-manganese, manganese-molybdenum and chrome-nickel steels, using the lead-pot, salt-bath, cyanide and electric-furnace methods of heat-treatment. While the conclusion reached was that very little difference in the performance of any of these steels with normal treatment could be detected, the high wear-value of cyanide-treated chrome-steel and the even better value of chrome-vanadium steel when cyanide treated were the two outstanding features. In every case a metallurgical representative from the steel mill worked with the organization's metallurgist so as to take advantage of all the knowledge available for getting the best results from each type of steel. These tests furnished the basis for probably the most vital information required for motor-car-transmission design, the ratio of dynamometer hours to miles of field operation of the car in intermediate gear. This figure varied from 1:1000 to 1:8000, a safe average being 1:3000.

A study of the characteristics of the wear of the first series of dynamometer tests revived interest in some calculations and tests that had previously been made on modified-addenda gears, it being apparent that the wear on the gear tooth bore a definite relation to the square inches of active tooth surface rather than to merely the pressure per lineal inch on the tooth. This resulted in an effort to make the number of square inches of active tooth surface on each pair of gears as nearly equal as possible, with the result that a reduction of 20 per cent in the weight of a transmission of a given capacity was effected.

Another example of coordinated activity was the grinding of gear teeth. About 3 years ago the decision was made that the gear teeth should be ground. After installing a battery of gear-tooth grinding-machines operating on the generating principle, it was found that a consistently good production could not be obtained and the form-wheel type of machine was substituted, the reason for the change being that the principles of approved grinding-machine obstruction and grinding-wheel practice were not violated and that the degree of accuracy required is merely a matter of machine maintenance and proper attention to the forming device.

As the result of the fullest cooperation from the steel mill, the forge shop, the heat-treating and metallurgical departments, the machine-tool builder, the grinding-wheel manufacturer and the engineer, the immediate problems of the factory and its customer have been solved, the gear-noise problem has not recurred to any great extent and the likelihood of its recurring in the future has been reduced. A greatly improved product, with in most instances a lowered cost has followed, but the most valuable accomplishment in the author's opinion is the bringing about of a spirit of cooperation in the shop and with the customer.

FREQUENT "storms" of trouble, arising from no apparently specific cause, affect the manufacturing phases of the automotive industry adversely. This is especially true in gear-manufacturing shops. I refer particularly to the periodical recurrence of problems of gear noise and wear that often throw the gear shop into a turmoil, after which it is difficult to determine exactly what correctives were applied or what assurance exists that the turmoil will not recur. Much has been written and discussed about the mathematics and the geometry of gears which should overcome all such trouble, but unfortunately it never has been entirely overcome. I will therefore present a novel experience in the clearing up of one of these storms of more than average violence which struck our organization some 2 years ago and which offered an opportunity for a more thorough analysis than its predecessors.

Along with the analyses of our own shop conditions came the usual suggestions that we use such and such a process, or such and such a steel, "because so and so has used it and never has any trouble." Probably, all have heard these claims made and, if anyone has taken the time to run them down, he has found that "so and so" has about as much trouble as he does, whether it is of the same nature or not. I have always given careful consideration to the fact that any present commercial development is the result of evolution and the coordination of several branches and that no one man or no one branch is, individually, capable of accomplishing anything without the understanding and coordination of several other men or of several associate branches. Further, this evolution in the automotive industry has been at times too rapid to permit the proper recasting of the situation when some new feature is introduced, and I believe you will agree that this is the source of many of our problems today. Our motor-car transmis-

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sions of today are a fine example of this evolution. The materials, the designs and even the functional requirements we use are a summation of the developed demand, and the process determining the material available and most of the major steps has come about through commercial expediency and not through previously determined figures of the designer.

Analysis of the Product

A laboratory and a dynamometer analysis of our product showed that it was in every way up to the average when compared with several specimens of our contemporaries' output. We found evidence that the other fellows had troubles very similar to ours, and that their remedies were about the same. They were using the best materials, designs and processes that they had been able to develop. Throughout our entire preliminary investigation evidence existed that, if we could coordinate the important points found in each specialty from the steel mill, carrying the coordination through the heat-treatment, the details of tooth form, the mathematics of gear action and the process of manufacture, some long strides could be made toward improving the performance and decreasing the cost of the product.

Realizing to what extent the present product had resulted from adopting one commercial development after another, and also the extent to which our entire industrial structure had been built up through the purchase of equipment and the training of men along established lines, we endeavored to abandon all loyalty to the present status of things and to assume that, should we be called upon to design the best transmission, judged from the horsepower-hours and the dollars standpoints, we did not know what materials, what process or what size to use. This may seem a startling statement, but try putting aside your own prejudices in favor of your own lines as you have developed them, and ask yourself the same questions. In every case the answer is, "we are following our present practice because it is the best way we have been able to establish for our shop to date." It is true that the engineer may have certain designs and the steel mills may have other steels that they believe would be better, and so on through every branch but, until all these can be coordinated, the actual step in progress cannot be made.

To substantiate this statement, let us review a bit of history. The first horseless carriage used belts, friction devices or gears to secure the desired driving ratios. The fact that gears could transmit the required power in very much less space and with much more reliability quickly eliminated the other means of transmission, and the motor-car builder turned to the gear specialist for his best product. He took what we might call the Brown & Sharpe 14½-deg. pressure-angle, involute-form cut-gear. These gears were all of the interchangeable system, not because the interchangeable system was the best thing for the motor-car transmission but because the best gears developed to that date were developed along the interchangeable system. Wear on the soft-steel gears in planetary and in individual-clutch-type transmissions, and the advent of the sliding-gear transmission, immediately called for a hardened gear-tooth. The best commercial development available was the pack hardening of low-carbon steel. This material, however, has such a low permissible stress that, when used on the 14½-deg. pressure-angle involute-tooth of full depth, it made stripped gears the nightmare of the motorist.

The gear maker remedied this defect with a 20-deg. pressure-angle stub-tooth involute-gear, still on the interchangeable system, which, having a broader base and a reasonable gear action, did much toward overcoming the stripping of teeth. At this time, a few builders went a step farther and developed the 20-deg. pressure-angle full-depth tooth, which gave a better gear-tooth action and sacrificed very little strength. However, I believe you will all agree that, up to very recently, the 20-deg. stub-tooth has predominated in the motor-car transmission field.

As quantity production gained, we began to feel the commercial shortcomings and hazards of the pack-hardening process and we welcomed the advent of high-carbon alloy-steel, which became available about 1911 at a price that made its use commercially practicable. Many of these steels were known years before, it is true, but their price was prohibitive; also, the treacherous nature of the results due to handling them with any available equipment barred them from serious consideration. After the advent of the high-carbon alloy-steels, did we check back to find the best tooth-form to use to take advantage of the physical characteristics of this steel? We definitely did not. We continued with our 20-deg. stub-tooth, because this was the best thing we had developed to date. We accepted what pitting and wear we got as inherent in this type of steel. Some few of us continued with the pack-hardened gear. Then alloy-steels became available, allowing the adherents of this method to hold their ground in competition with those adopting the high-carbon oil-treated steels.

Under the commercial pressure for lower cost and lighter units, we began calculating closer to the higher stress-values of our alloy-steel and making our transmission smaller, finally reaching a point where wear and pitting became serious factors. A few manufacturers, realizing that the full-depth tooth had a better wear-value and a better tooth-action than the stub tooth, went back to the use of 20-deg. pressure-angle full-pitch teeth on all or at least on the countershaft constant-mesh gears and the intermediate gears, thus making half a step in the right direction. From several conferences I have attended and from discussions I have had with gear makers, aside from a few individual steps, this problem is still before the gear-making fraternity. I believe its only cure is in coordinating the efforts of all divisions involved.

Efforts Toward Coordination

As stated previously, the shop was in trouble. We have not left the shop to flounder around for any length of time, for most of the foregoing points were presented and threshed out in a conference that required but little longer than does the reading of these items. The valuable feature was that we were able to lead the shop step by step as our dynamometer results developed. The first accusation to be answered was that our gears wore and pitted because they were soft. This came about through the tendency of the shop to run to the low range of the hardness specification as a precaution against distortion. We were using a chrome-carbon steel of No. 5150 S. A. E. analysis, having some years previously substituted it for the chrome-vanadium No. 6145 steel originally used. Short runs on the dynamometer readily showed that, within a liberal range on either side of the specific hardness, no appreciable change existed in the wear value and, going a step farther, we water quenched some of this steel to No. 96 Shore hardness and got practically the same pitting and wear value as we did from soft specimens at No. 65 Shore hardness; thus, we immediately relieved the shop of the soft-gear trouble.

The next step was to determine the best treatment for the steel we were using. After finding the highest performance of our No. 5150 steel, we checked this by a similar test through practically the entire series of high-carbon oil-hardening steels, in every case having a metallurgical representative from the steel mill work with our metallurgist so as to take advantage of all the knowledge available for getting the best results for each type of steel. In these tests we went thoroughly through the chrome-carbon, chrome-vanadium, chrome-manganese, manganese-molybdenum and chrome-nickel steels, using lead-pot, salt-bath, cyanide and electric-furnace heat-treatment. In some cases the steel was furnished to us in the rolled bar and was carried through the forging, normalizing machining, and final treatment under the combined supervision of a steel-mill metallurgist and our own. In other instances the forgings were taken from the stock of the manufacturers using these steels, the normalizing was done in their plant under their supervision, the forgings were forwarded to us for machining, returned to them for final treatment and finally returned to us for dynamometer test. All through these tests the same gears, the same tooth form and the same dynamometer loads and speeds were maintained. Special attention was paid to the cyanide-bath heating of these steels, as it was found that two of our contemporaries were using this type of steel and getting outstanding results, the main difference between their treatment and the others being that the finished product was heated in a cyanide bath for its final quench. The details of these runs would make a long story; however, the conclusion reached was that very little difference exists in the performance of any of these steels with normal treatment. The two outstanding features were the high wear-value of cyanide-treated chrome-steel, and the still better value of chrome-vanadium steel when cyanide treated.

Cyanide treating of a 7-9-pitch gearset, with which we were having trouble due to period noise that occurred after very slight wear, furnished the shop with an immediate way out. The dynamometer test of this gearset showed that pitting on the original treatment was traceable within 2 hr. and that its average life was 8 to 10 hr. on full rated-dynamometer load; whereas, the same gearset gave an average life of 30 hr. when cyanide-treated without any other modification. This series of tests gave the basis for probably the most vital information required for motor-car-transmission design; that is, the ratio of dynamometer hours to thousands of miles of field operation of the car.

Transmission-Performance Comparisons

Some 50 comparisons of transmissions of known mileage, in known territories, were made with dynamometer gears of various stages of wear under known load and length of time, together with comparisons of material analysis, impact value, structure and hardness. A low value of 1000 miles of car use per hour of dynamometer load in intermediate gear was established and a high value of 8000 miles of car use per hour of dynamometer load in intermediate gear was found. All figures indicated a safe average of 3000 miles of car use per hour of dynamometer load in intermediate gear. In giving this average for passenger-car service, we find that passenger cars used in stage-coach service in mountainous or in sand-road localities demand a transmission based on the 1000 miles of car use per hour of dynamometer load and, for trouble-free service, the transmission should stand up for at least 100 hr.

The study of the characteristics of the wear of the first series of dynamometer tests revived interest in some calculations and tests we had made on modified-addenda gears, but in which we had not been able to interest anyone. This is another example of the necessity of coordinating these bits of knowledge before definite steps can be taken. Having determined the values of various heat-treatments and steels in the stub-tooth form, we next applied them to full-pitch 20-deg. pressure-angle involute-teeth, using, however, the most favorable of the previous combinations only. These tests resulted in finding that, with an electric-furnace treatment on chrome steel, wherein a 7-9-pitch gearset would show signs of pitting in 2 hr. and would show a total life of 10 hr., a 7-pitch gearset of otherwise the same dimensions and treatment would run from 26 to 30 hr. before showing signs of pitting and would show an average life of 70 hr.

In measuring the life of a gearset, we determined by comparison with field-test jobs the amount of wear permissible before objectionable noise occurred, setting for a standard the point at which the gears would be replaced if the car were being overhauled. We also found that the cyanide-treated chrome-vanadium 7-pitch gearset, having otherwise the same design, practically eliminated pitting; a life of from 100 to 125 hr. occurred before any perceptible wear showed; and better than 200 hr. can be counted on as an average life of the gear. A 3½ per cent nickel pack-hardened 7-9-pitch gearset run on the same test showed 72 hr. before a noticeable wear and an ultimate life of 150 hr.

The same general characteristics apply not only on the fine-pitch passenger-car units, but to the heavier pitch heavy-duty truck-gears as well, although the exact ratios are not maintained; that is, in the heavier pitches for heavier duties, the differences between these gears is not so great as shown by test on the lighter duty gears; however, we have not gone far enough into the heavy-duty tests to determine the exact value.

Regarding our modified-addenda set, it was apparent that wear on the gear teeth bore a definite relation to the square inches of active tooth, rather than merely to the pressure per lineal inch on the tooth. This led us into an endeavor to make the square inches of active-tooth surface on each pair of gears as nearly equal as possible; that is, to make the active-tooth face on a pinion as much greater than the active-tooth face on its mating gear as its ratio to that gear. By balancing out a transmission design in this manner, we have been able to reduce the weight of a transmission of a given capacity by 20 per cent.

Coordinated Activities

Concerning the subject of coordinated activities, our reactions on gear-tooth grinding are of interest. Some 3 years ago, our organization reacted to the logic that gear teeth should be ground for the same reason that shafts and other parts are ground, and that the only thing that kept us from doing it was lack of suitable machines. This indicates another case of the necessity of cooperation between the machine-tool builder and the designer. It is unquestionably just as illogical to run hardened gear-teeth, which have merely been hob or shaper cut and then put through the fire, together, as it would be to put a good lathe finish on a shaft, put it through a heat-treatment and try to assemble the bearings and other running parts; and, in spite of some of the differences that may be drawn in this comparison, we still believe in grinding, although we are doing very little of it at present.

At the period first mentioned we inspected the entire field of gear-tooth grinding-equipment then offered and, being firm believers in the generating process, we selected and purchased a battery of machines that appeared to be fundamentally correct and that gave very good results on demonstration. These machines did very creditable work in salvaging, but we were unable to get down to a good commercial basis by their use; in fact, by using these grinding machines as a club over the production end of the shop, it developed that we could consistently cut as satisfactory gears as we could grind.

Shortly after our original purchase, we inherited from another organization part of a battery of a newer type of generating grinding-machine. We obtained about the same reaction as from our original installation, our findings being that, while both of these machines and their generating principle were all right on paper, we could not keep them working in the shop. In addition, we had considerable wheel trouble which the grinding-wheel people seemed unable to eliminate. The curve-generator mechanism is not of sufficient ruggedness to maintain its accuracy under shop production-conditions; also, it appears that the method of taking the cut violates good grinding-practice and presents a grinding-wheel condition with which the abrasive manufacturers are not able to cope.

Form-Wheel Type of Grinding Machine

The furnishing of ground gears to meet the need of a quiet-running installation having a very exacting backlash-requirement caused us to look into the form-wheel type of grinding machine. In spite of all the niceties of the generating outfit, we found that we could get consistently accurate gears from the form-wheel type of machine only, the apparent reason being that approved grinding-machine construction and approved grinding-wheel practice are not violated; also, the degree of accuracy required is merely a matter of reasonable machine maintenance and proper attention to the forming device. Therefore, the form-wheel type of grinding machine today is far closer to the commercial ideal than any other. However, it is again proved to be a matter of the proper coordination of the machine-tool builder, the abrasive-wheel maker and the transmission maker to bring about the day when all gears will be ground on the teeth.

From such study as we have made of ground gears in the materials already mentioned, it also looks as though it will call for a recast of the entire situation as to materials and heat-treatments; for, from our tests, it is evident that merely grinding present types of gear will not give the best results; in fact, several outstanding experiments have been made in the industry that point to some very interesting ultimate developments in this line.

By obtaining the fullest cooperation from the steel mill, the forge shop, the heat-treating and the metallurgical department, the machine-tool builder, the cutter maker and the engineer, we have been able, step by step, to solve the immediate problems of our shop and our customers, to prevent the recurrence of any "storms" to date, to see fewer clouds on the horizon, and to improve our product greatly without adding to its cost; in fact, in most instances, we have lowered detail cost, but the most valuable accomplishment is to have brought about a spirit of cooperation in the shop and with the customer that is high above the average.

I do not contend that any of these facts are new. In fact, we have individual records of most of these items ranging from 10 to 80 years back, but I do present this assemblage of thoughts and the reaction that they have had on our shop for your consideration as a basis from which to attack similar problems when they arise in your own organizations. The fact that these items are individually old and known to most of you is all the more proof that the only important steps of progress are made by coordinating all branches behind each step.

AMERICAN BUYING-POWER AND PRICE-LEVEL

THE proper point of departure for a diagnosis of the price situation in a country like the United States is a study of the total purchasing power of the population—that is, of the national income. For changes in the national income, whether favorable or adverse, will inevitably be reflected in corresponding upward or downward movements of the general price-level.

An excellent general idea of the changes that have occurred in the national income of the American people since the years immediately preceding the European War is afforded by the statistical analysis just completed by the National Bureau of Economical Research, New York City, and published under the title Income in the Various States—Its Sources and Distribution in 1919, 1920 and 1921. From the resume of this highly instructive study, it appears that the total current income of the American people in 1913 may be estimated at \$32,000,000,000, while in 1919 it was \$67,254,000,000, rising to \$74,158,000,000 in 1920 and then declining to \$62,736,000,000 in the year of acute post-war depression, 1921. By current income this authority means the total national income less the estimated amount of the business savings of the Country,—that is, that part of the national income which is directly effective for the purchase of goods and services, thus representing the actual buying-power of the population as a whole. The estimates of the National Bureau of Economic Research for the national income and the current income of the Country in the years 1922, 1923 and 1924 have not yet been made public, being, we understand, in course of preparation; but from the studies of other economists in this field, notably Dr. B. M. Anderson, Jr., and with some assistance from the income-tax statistics published by the Treasury Department, we may safely conclude that the current income for 1922 was substantially larger than that for 1921, that a further increase occurred in 1923 to a figure only moderately lower than that for 1920, and that, while some decrease was reported in 1924, the Country's current income was greater last year than in any preceding years of record except 1920 and 1923. At least, without doubt the current income of the American people in 1924 was considerably more than double that of 1913; and since current income means effective buying-power this great increase was immediately reflected in the price fabric or price-level of the Country—the latter, when all kinds of prices and not merely commodity prices are taken into the reckoning, being not far from twice as high as that obtaining in 1913. Thus, current income or buying-power was in equilibrium with the price fabric in 1924 and the price fabric was therefore perfectly stable—a state of things that has not since changed to any great extent.—A. R. Marsh in *Economic World.*

Inspection Methods

By C. J. Ross[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

WITH the passing of the apprenticeship system and the introduction of the present method of employing unskilled labor on a piecework basis for assembling, careful inspection has become a necessity. Under these conditions, the only way in which the product can be held to the required standards is to make the component parts fit accurately. If the inspection is adequate, parts can be held to closer limits and cheaper labor can be used in the assembling process.

Believing that no reason can exist for failure to maintain standards of accuracy if the ratio of the number of men engaged in production to one inspector does not exceed 15 to 1, the officials of the Buick Company have worked out a system, similar in many respects to a budget, in which a certain ratio of production hours to inspection hours is allowed in each plant, the number depending upon the nature of the work and varying from about 10 to 1 in the engine plant to about 34 to 1 in the gray-iron foundry. In actual operation these ratios were usually reduced.

The inspection department is divided into four divisions, each of which is under the jurisdiction of a divisional inspector who reports directly to the general superintendent. All major parts are given 100-per cent inspection. Parts purchased from other companies are given 10-per cent inspection, but if any are found faulty all are checked.

The process of inspection is followed from the time the incoming raw material is checked for quality by the metallurgical department, as it passes through the various steps of production, until it reaches the final assembling line. In general, inspection by pin and snap gages of the go and no-go type has been found most satisfactory, because this method gives quicker inspection and establishes definite limits beyond which parts are not allowed to pass.

Many of the testing devices employed are similar to those in common use in the industry but others have been specially devised to meet particular needs. Several of these containing noteworthy improvements are described in detail and illustrated. Extensive application is made of spark testing, both of the raw material and of parts coming from the heat-treatment. By this method not only can steels that may have become mixed be readily sorted, but the carbon-content and the presence of inclusions can be quickly and accurately determined, and the percentages of nickel, chromium, tungsten and vanadium present in an alloy-steel can be fairly closely estimated. Among the special devices described are those for inspecting crankshafts, cylinder bores, flywheels, camshafts, differential carriers, steering-knuckles, universal-joint yokes, chassis springs, the inside diameter of steel flywheel rings, wheel felloes, and the toe-in and camber of axles.

INSPECTORS have been called a necessary evil. Formerly, mechanics served apprenticeships, were well trained, and their work was of so high a quality that little inspection was required. But the day of apprenticeship has passed. No longer does the incentive to learn a trade exist, for any novice can be taught to insert a cotter-pin and by performing this operation on a piecework basis can earn better wages than he could by serving as an apprentice in learning a trade. Consequently, boys are not content to remain long in one department, but are anxious to work on the assembling line where they can make more money.

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TABLE 1—TOTAL NUMBER OF INSPECTION HOURS PER UNIT PART PRODUCED DURING THE 3 YEARS ENDED AUG. 31, 1924

Name of Part	Sept. 1, 1921, to Aug. 31, 1922	Sept. 1, 1922, to Aug. 31, 1923	Sept. 1, 1923, to Aug. 31, 1924
Engine	3.5	3.8	3.7
Axle	0.9	0.9	1.0
Transmission	0.8	0.7	1.0
Forgings, per ton	..	..	4.4
Average for entire car	12.3	11.5	11.3

When unskilled labor is used in assembling, the only way in which the product can be held to the required standards is to make the component parts fit accurately. With adequate inspection, parts can be held to closer limits and cheaper labor can be used in the assembling process.

To stay in the market, a motor vehicle must be well made. To continue in the race for popular favor, an automobile must continually become better. Holding this as a guiding principle, our product is watched closely, both during its production and after it leaves the factory.

As soon as production is started on a new model, a finished car is brought in and torn down to see how closely it complies with the requirements. This is repeated every few days. Engines are checked every day, two inspectors being kept constantly on this work.

Detailed reports of breakdowns in service are received monthly from every distributing territory. With a view of eliminating defects and replacing the less durable parts with more durable ones, from 7 to 14 cars are kept on the road in tryouts. Standards are set and no one is excused for failure to maintain these standards.

RATIO OF PRODUCTION HOURS TO INSPECTION HOURS

During production, we believe that no reason can exist for failure to meet the standards of accuracy if the ratio of production men to each inspector does not exceed 15 to 1. As worked out by our company, a certain ratio of production hours to inspection hours is allowed in each

TABLE 2—NUMBER OF INSPECTION HOURS PER $100 WORTH OF PRODUCTIVE LABOR IN THE LAST 4 YEARS

Name of Plant	Sept. 1, 1921, to Aug. 31, 1922	Sept. 1, 1922, to Aug. 31, 1923	Sept. 1, 1923, to Aug. 31, 1924	Sept. 1, 1924, to Aug. 31, 1925
Forging	14.8	11.9	10.4	7.0
Engine	17.5	19.0	18.6	14.7
Sheet Metal	...	9.9	13.4	12.6
Transmission	9.2	8.1	11.6	12.5
Axle	12.7	12.7	14.1	13.7
Average for All Plants	13.9	13.0	12.5	11.7

plant, the number varying in the different plants and depending upon the nature of the work. This system practically amounts to the working out of a budget. Each plant must live within its allowance. In March, the average size of these operating units of inspection throughout the entire plant was 12.75 men per inspector; on May 30, the ratio was 11.28; and for the week ended Aug. 8, it was 13.3.

When computed on a basis of $100 worth of productive labor, the average number of inspection hours for the entire plant for the year ended Aug. 31, 1922, was 13.9; for the year ended Aug. 31, 1923, 13.0; and for the year ended Aug. 31, 1924, 12.5. Similarly, the number of inspection hours per $100 worth of productive labor required for several of the major units is given in Table 1. When the computation is reduced to the number of inspection hours per unit part, the results are those shown in Table 2.

In the engine plant the number of productive hours allowed per hour of inspection was 10.0, whereas the actual operating ratio was 9.8 to 1.0. For other parts these figures were as follows: axle, 12.1 as against 15.0; transmission, 12.0 as against 12.8; and gray-iron foundry, 34.0 as against 35.0, as is shown in Table 3.

TABLE 3—RATIO OF THE PRODUCTION HOURS ALLOWED TO ONE INSPECTION HOUR AND THE RATIO AT WHICH SEVERAL PLANTS WERE RUNNING DURING THE WEEK ENDED AUG. 8, 1925, AND THE YEAR ENDED AUG. 31, 1924

Name of Plant	Ratio Allowed, Hr.	Running Ratio, Hr., for Week Ending Aug. 8, 1925	Running Ratio, Hr., for the Year, Sept. 1, 1923, to Aug. 31, 1924
Engine	10.0	9.8	10.1
Axle	12.1	15.0	12.6
Transmission	12.0	12.8	12.1
Gray-Iron Foundry	34.0	35.0	32.6
Brass and Aluminum Foundry	28.0	...	21.0

The inspection department is divided into four divisions, each of which is under the jurisdiction of a divisional inspector who reports directly to the general superintendent. In general, inspection by pin and snap gages of the go and no-go type has been found to be the most satisfactory; they give quick inspection and are considered superior to micrometers for this work. Parts either pass or do not pass. Limits are set beyond which they are not allowed to go. All finished parts purchased from other companies are given 10-per cent inspection. But if any are found faulty, all parts are checked. Inspection begins with the receipt of the incoming raw material, which is carefully checked by the metallurgical department to ensure that it complies with specifications.

Metallurgical Inspection

The metallurgical department includes large and well equipped laboratories for the testing of the various materials entering into the construction of cars. In addition, tests are made on so-called "non-productive" materials that are essential to plant operation and maintenance. Facilities are provided for making accelerated corrosion tests on metals, fatigue tests on springs, tensile and compression tests on steels and cement, hardness tests by the Brinell, Shore and Rockwell methods, transverse tests on fabricated parts such as axles, torsion tests, impact tests by the Izod method, drop tests on wheels, and other tests of a special nature.

In addition to the various tests made on raw materials

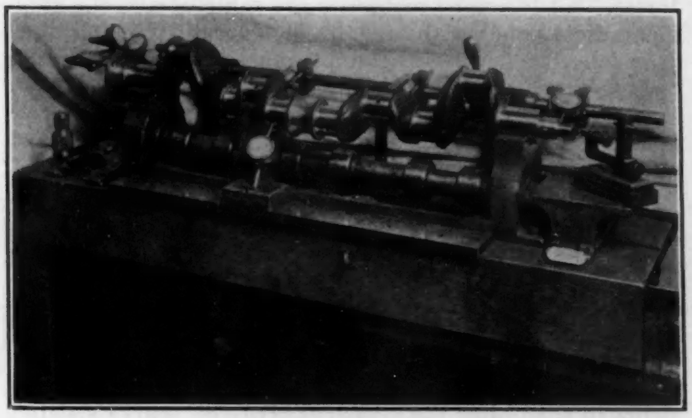

Fig. 1—Fixture for Checking Crankshafts
This Fixture Is Used To Check the Spacing of All Pin Bearings, the Length of Throw, the Location of the Keyway with Respect to the Throw and To Indicate All Main Gear and Flywheel Bearings. All These Checks, Excepting Those for Locating the Keyway and the Length of Throw, Are Made at One Revolution of the Shaft

and finished parts, the various metallurgical processes require the most careful supervision. The heat-treating furnaces are equipped with recording pyrometers and automatically controlled burners and a checking system is employed that practically prevents incorrect temperatures.

Not only must raw materials meet the most rigid requirements, but the different processes that affect the strength and toughness of the part are carefully supervised and the finished article is tested to make sure that the desired quality is maintained. A corps of special metallurgical inspectors is stationed in the various fac-

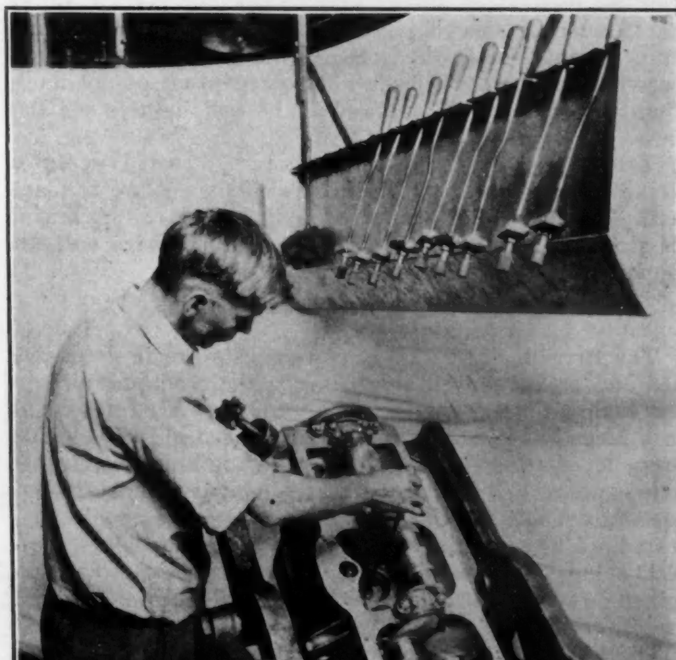

Fig. 2—Paddle Gages for Determining Size of Cylinder Bores and Selecting Piston Fits
These Gages Are Ground into the Shape of a Ball and Are Made in Steps of 0.0005 In., Giving a Very Sensitive "Feel" and Showing the Least Out-of-Round Condition

tories. All incoming materials are sampled and the shipments held pending the results of laboratory tests. Steel is received and classified according to heat number and two or more samples from each heat are analyzed and, in some cases, subjected to physical test before acceptance. Such materials as babbitt metal are examined under the microscope.

The Spark Test

A rather novel method of inspection extensively used is the spark test, a rapid method of determining chemical composition. This test, although by no means new, has only recently been adopted as a routine method of inspection in large scale production. The spark test depends on the fact that minute quantities of certain elements in steel alter the appearance of the sparks emitted when the material is ground on an abrasive wheel. Carbon, the most important element in steel, excepting iron, has a very pronounced influence on the spark. In testing medium and low-carbon steels by this method, the carbon can be determined within 0.02 or 0.03 per cent by using suitable standards of known carbon-content. Nickel in steel also gives a characteristic spark, as do chromium, tungsten and vanadium. The percentages of these elements cannot be determined so closely as those of carbon, but they are susceptible to fairly accurate estimates. One-half of 1 per cent of nickel can be readily detected, which allows easy differentiation to be made between standard S.A.E. steels.

In sorting mixed stock, the spark test is of very great help. Individual bars can be rapidly and cheaply "sparked" and placed in their proper classifications. In this plant, all piston-pin tubing stock is spark tested as a routine method of inspection. Stock for certain other parts, such as shackle-bolts, is handled in the same way. It is essential that the cores of these parts, which are case-hardened, should have a carbon-content of not more than 0.25 per cent, for a higher carbon induces brittleness.

The spark test is performed with a small portable grinding machine that can be carried from place to place and plugged into a light-socket by a long cord. A binful of stock can be sparked on the ends of the bars without removing or handling the material.

Other Tests

The Brinell, Shore and Rockwell tests are in extensive use and are employed according to their adaptability to the various jobs. The Brinell test is very accurate within a large range of hardness and is used on axle-shafts, propeller-shafts, steering-arms, steering-knuckles, front-axle centers, and numerous high-duty parts that are not case-hardened. All the vital front-axle parts are Brinell tested. This test is also used on cylinder-blocks, two blocks being cut up each day and the hardness determined on the bore. Brass, bronze and aluminum castings are checked by the Brinell method.

The Shore test is used chiefly on case-hardened parts and on transmission gears. Piston-pins, cam-rollers, king-bolts, and valves are among the parts subjected to this test. The Rockwell is in reality a modified form of Brinell test and has its own field of usefulness, being used at the present time in testing piston-rings and flywheel rings.

The time-honored file test is also in extensive use. For certain case-hardened parts it is considered preferable to other methods of testing. Many parts are file tested before grinding and are tested by the Shore method after being ground.

Springs

Chassis springs, which are manufactured outside the plant, are purchased under rigid specifications as to chemical and physical properties. These springs are Brinell tested at the source of supply and a certain percentage of the Brinell readings is checked at the plant. In addition, each spring is weighed on a special machine that will be described later, to determine whether it has the proper deflection under load. Valve and clutch springs are weighed in a similar manner and samples are sent to the laboratory for chemical analysis and microscopic examination.

Of great importance is the inspection for seams and other physical defects that sometimes make their appearance in the steel used for high-duty parts. A part may be of the highest quality with the exception of a tiny crack, which, under the repeated stresses of service, would finally result in rupture. The inspection for such defects is painstaking in the extreme and nothing is left undone to make sure that all unsound parts have been eliminated.

Brake-linings are tested on a special type of machine in which the band is wrapped on a rotating drum in a manner closely approximating the conditions of service. This is an accelerated test requiring the application of water for cooling. The coefficient of friction is obtained and the general performance of the lining is noted at the end of the test. Two samples from each shipment are tested by this method.

The laboratory is provided with a special machine for testing speedometers. Six complete speedometers, including standard drive shafts such as are used on the car, are set up in a suitable fixture and driven by an electric motor through a gear-reduction box. The speedometers under test are driven continuously at certain speeds, are checked for noise and for accuracy of speed indication, and are carefully watched for any faults that may develop.

Tests During Production

In addition to the metallurgical tests of the quality of the material entering into the product that have already been described, each step is watched carefully as the various parts proceed through the production process, and the parts are subjected to continued further tests to determine the accuracy of manufacture. These tests vary in character according to the importance of the part. Many of the testing devices employed are similar to those in common use in the industry, but others have been specially devised to meet particular needs.

Sheet-metal parts as a rule are given visual inspection only, surface finish being the principal point noted; some, however, such as fenders and hood-stock parts, are checked with contour gages. Every sheet-metal part has a master part with which the first pieces from a run are compared and other comparisons are made from time to time.

In the forging shop, new dies for drop-forgings are carefully inspected for imperfect follow, and the like, with the well-known lead test. Every hammerman is required to put his stamp on every axle, crankshaft and camshaft produced so that the part can be identified in case of defects.

The inspector in the hammer-shop watches the general shape of the forgings and notifies the foreman to stop work if the dies begin to show wear. After an axle, for example, has been forged, the inspector checks it for length, cold shuts, and the like, at the hammer. It then goes to a machine that stretches it to length and concaves

the spring pads; and it is again inspected for length. After it has been heat-treated, both ends are Brinell tested for hardness, and it is sent to the pickling department, is straightened, inspected for seams and other defects, and placed in a fixture where its demensions are checked. Camshafts and crankshafts undergo a somewhat similar treatment.

These and other parts not only receive subsequent and continual detail checking as they pass through the various machining, grinding and drilling operations, but before being assembled undergo a final inspection in which special gages and fixtures are used. Some of the major checking and inspection operations are as follows.

A special fixture, a view of which is shown in Fig. 1, is used to check the spacing of all crankpin bearings, the length of throw, the location of the keyway with respect to the throw, and to indicate all main gear and flywheel bearings. All these checks, excepting those for locating the keyway and the length of the throw, are made at one revolution of the crankshaft. This fixture has proved to be very quick and accurate, giving the inspector ample time in which to examine the shaft for other defects. The bearings are "miked" for size, out of roundness and taper, the tolerance of the taper being 0.0003 in. All oil-holes are tried to make sure that they are not plugged.

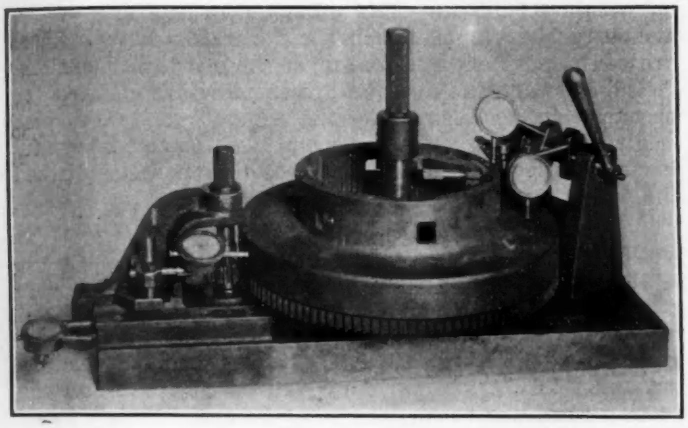

Fig. 3—Fixture for Checking Flywheels
Indicates the Runout of All Faces and of the Starting Gear; Also the Concentricity of the Clutch Teeth and the Backlash

Cylinder Heads and Blocks

In the inspection of the cylinder-head, the first operation is the checking of the valve-stem guide holes. The gage is set so that each valve-stem seat is centered with the guide holes and they are held within 0.0005 in. A check is made to ensure that the faces of the cylinder are parallel. The seats are checked for chatter and for clean-up in the grind. The combustion-chambers are checked for diameter and for depth of face. If the water test for leakage shows seepage, the cylinder is scrapped.

Cylinder bores are doubly checked, first by paddle gages, then by microgage. The method of checking by paddle gages is shown in Fig. 2. These gages are ground into the shape of a ball and are made in steps of 0.0005 in., giving a very sensitive "feel" and showing the least out-of-round condition. In conjunction with the microgage, they are used not only for determining the size of the bores, but also on the assembling floor in selecting piston fits. The bores are held parallel, and out-of-roundness and taper are held within 0.0005 in. A cylinder-block is also tested for being parallel on both faces, upper and lower. A check is made of the holes, size of the combustion-chamber and height of the block.

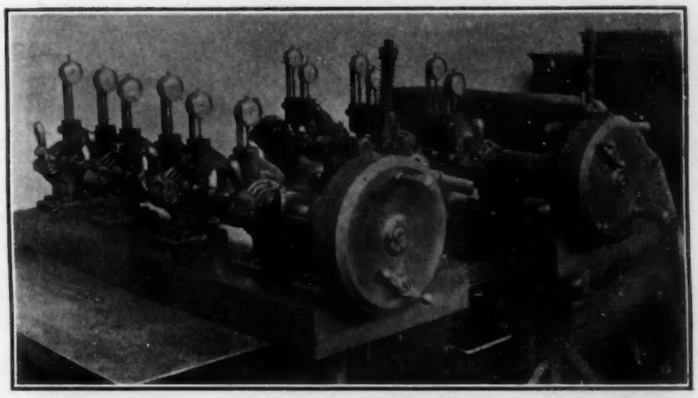

Fig. 4—Fixture for Checking Camshafts
This Is Used for Checking the Runout of Cams and Their Shape and Location with Respect to the Keyway. The Fixture at the Left Checks the Inlet Cams; That at the Right, the Exhaust Cams

The combustion-chamber is held accurately to length, because of the effect that variation of its length has on compression.

The length of the piston from the pin-hole to the top is also held close so that the compression will be correct. A check is made for the squareness of the piston with the pin hole, and for the diameter, depth and size of the pin hole; and a visual inspection ensures that no grinding-wheel marks have been left. Another gage tests the out-of-roundness of the piston and its fit is held within 0.0005 in.

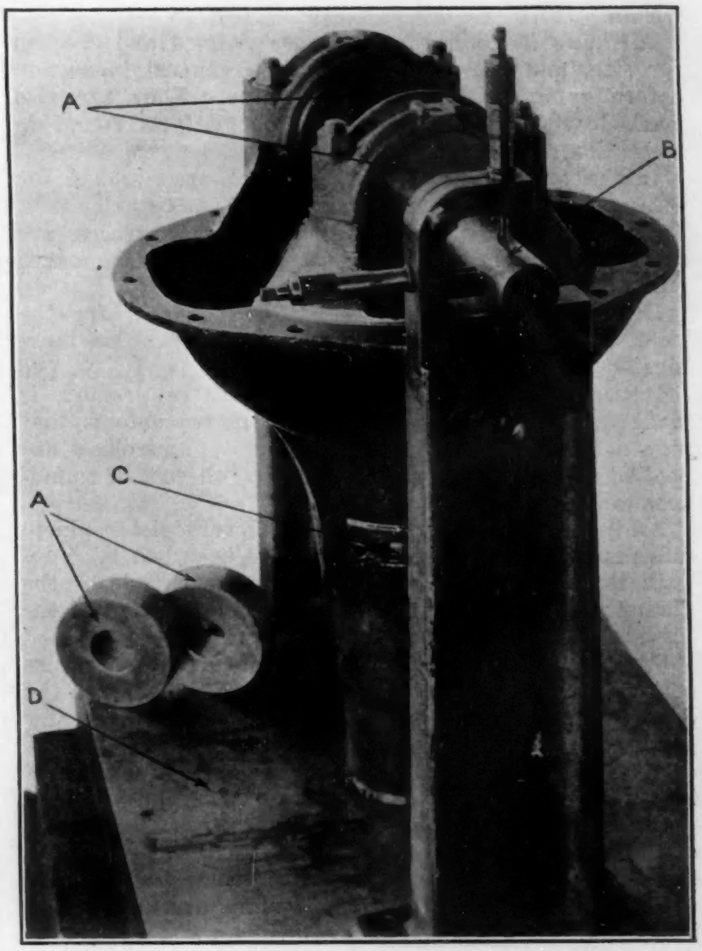

Fig. 5—Inspection of the Differential Carrier
This Fixture Determines the Alignment of the Differential Bearing with the Pinion Bearing

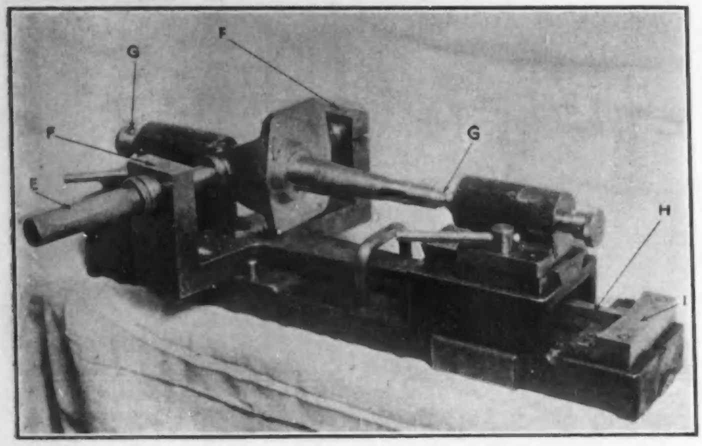

FIG. 6—FIXTURE FOR INSPECTING THE STEERING-KNUCKLE
Its Function Is to Test the Angle of the King-Bolt Hole with the Spindle Bearing That Produces the Camber of the Wheel

When running at full capacity about 4000 pistons are carried in stock, all of which are sorted and segregated into racks according to size and are marked with code numbers for selective fit, so that they can be assembled with cylinders of the proper size. A fixture tests the out-of-roundness of the pistons as they are lined up in the same fixture.

A special fixture, shown in Fig. 3, is used to check the runout of all faces of the flywheel of the starting gear, and also the concentricity of the clutch teeth and backlash. Every flywheel is checked for balance and is held within 1/8 oz.

All holes in connecting-rods are reamed and checked for size, and the rods are given a general inspection before going on the assembling line. They are also marked with code numbers so that defects found in inspection can be traced.

Intake and exhaust manifold faces are checked for being parallel with each other and with the cylinder face. Tapped holes are checked, and heater surfaces are checked 100 per cent for the angle that the surface makes with the cylinder.

Gear-case covers are checked 100 per cent for the location of holes and for the size of the trunnion bearings.

Inspection of all small parts, such as cam-rollers, is made under a magnifying glass to detect defects that may not be visible to the naked eye. Cam-rollers are held to a runout limit of 0.001 in. and the out-of-roundness to 0.0002 in.

An inspector looks at the inside of every piston pin to make sure that no scale or chips have been left.

In the water-pump coupling, a check is made of the diameter of the holes and of the size and location of the lugs, as regards their being central with the holes.

Timing-gears are checked for runout and for the size of holes. Particular attention is paid to the gears being concentric with the holes. All are checked with a master gear. Great care is taken to have the pitch diameter correct and to see that the gears have the proper backlash, which is held between 0.002 and 0.003 in.

Camshafts are checked for the size of the bearings and of the cams and are given a general visual inspection for the cleaning up of grinding-wheel marks and the like.

The pitch diameter of the oil-pump driving-gear is important. The bearings must run true; if they do not, they will soon "swipe" out the cam bushing. All bearings are checked for size and taper.

A special fixture, shown in Fig. 4, is used for checking the runout of cams and their shape and location with respect to the keyway. The fixture at the left of the illustration checks the inlet cams; the one at the right, the exhaust cams.

DELCO EQUIPMENT

Buick cars are equipped with what is known as the two-unit system of electrical equipment, that is, a generator with its distributor head assembly and a starting motor unit, both of which are purchased from Delco. Although these units are given very thorough inspection by the maker, they are given an additional inspection at our plant as a further precaution against unsatisfactory performance.

The first operation is the checking of the diameter of the pilot on the generator end of the frame; this must be within 0.0005 in. The diameter of the end of the armature shaft upon which the generator drive gear is pressed is next checked and must come within 0.0005 in.

The coils and the distributor assembly are checked for breakage in shipment. As the contact points are also easily thrown out of adjustment in shipment, a careful inspection is given of the width of the opening between the points and their proper alignment.

The end-play of the armature, when the driving gear is in place, must lie between 0.004 and 0.008 in. The generators are then placed on an inspection fixture and are driven by adjustable-speed alternating-current motors. The charging rate when cold must range between 15 to 18 amp. at the peak. Operation of the cut-out relay is checked for both the cutting out and the cutting in of the battery circuit. All unnecessary noise, such as that produced by gears, brushes, and the like, is eliminated.

No regular inspection is made of the starting motor. All units that do not perform properly either during the block test, the silent test, or while being assembled, are removed and repaired. In case trouble develops, a temporary receiving inspection is instituted until the trouble has been removed. A resident representative of the manufacturer is present to service all defects for which

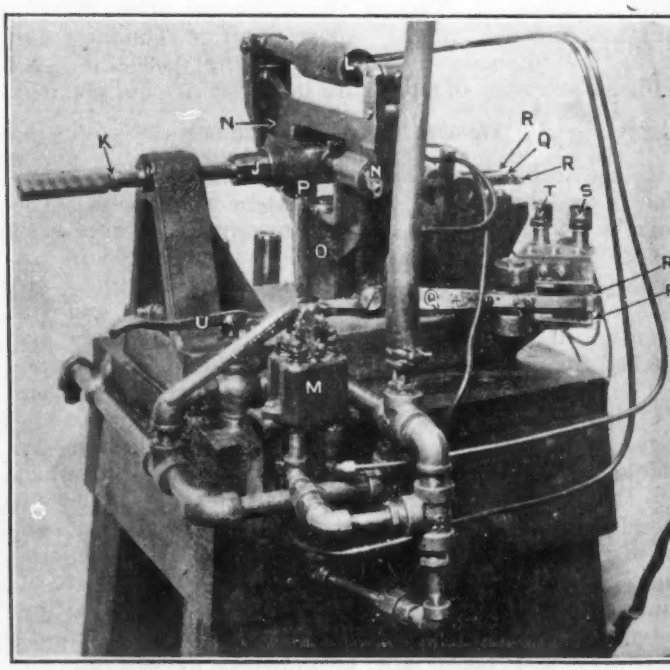

FIG. 7—FIXTURE FOR TESTING UNIVERSAL-JOINT YOKES
This Device Checks the Centers of Universal-Joint Yokes for Being Central with the Spline Hole and Also Shows Whether the Centers Are at Right-Angles with the Center-Line

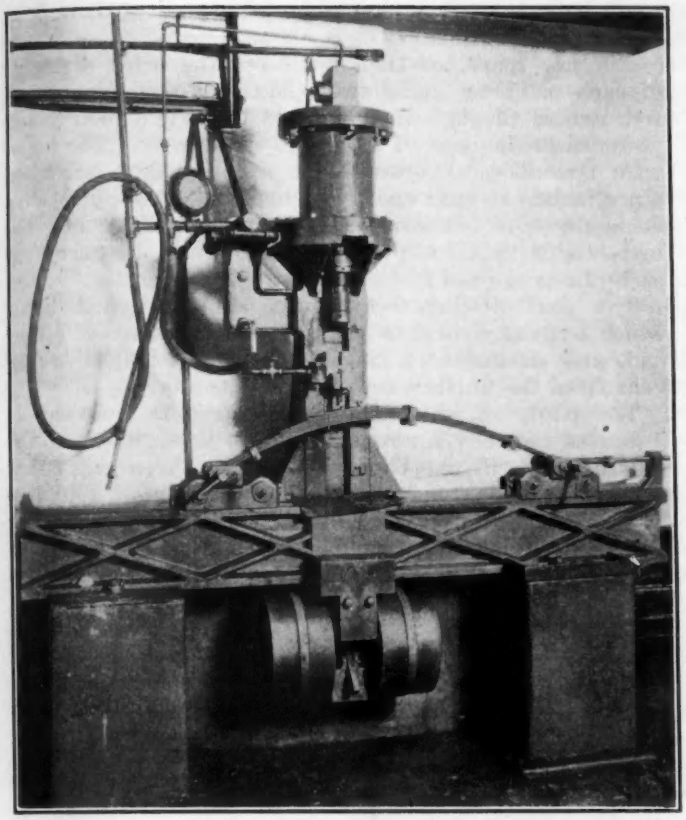

FIG. 8—INSPECTION OF CHASSIS SPRINGS
The Points Covered in This Test Include the Free Height of the Spring, Its Deflection under Normal Load, the Width between the Spring Eyes, the Diameter of the Hole in the Spring-Bolt Bushing, and the Alignment of the Bolt Holes with One Another

the vendor is responsible, and also to provide a stock of service parts.

The inspection department maintains close contact with the engine assembling line, the final engine inspection, the final engine repair, and the final car assembling and inspection, in order that any unexpected defect that is discovered may be called to the attention of the receiving inspector.

ASSEMBLING LINE

In the assembling line, every fourth or fifth man inspects the work of those who have preceded him. Camshafts are selected according to the size necessary to fit the bearings properly. At the end of the line three men continually check engines for bearing and piston fits to ensure that nothing has been overlooked.

A certain number of engines are dismantled daily by men who are entirely independent of any other department so that their complaints are unbiased. They report directly to the factory manager and to the chief inspector.

In assembling crankshafts, cylinders and pistons, code numbers are matched, so the proper fits will be obtained. Engines are given from 2 to 3-hr. test to determine their running quality. During the final engine inspection special attention is paid to gear noise and the lashing of the engine. The inspection is visual and aural, its object being to note any minor defect that may have been overlooked. During this test the engines are run on city gas instead of gasoline.

TRANSMISSION SPLINE SHAFT

When the lathework upon the spline shaft has been completed previously to entering the heat-treating department, the inspector, using Johannson adjustable limit gages, checks all the diameters that are to be ground, including about 0.020 in. of additional metal usually left for grinding. The same inspector uses a profile gage that hooks over one end of the shaft and gives the dimensions between all faces and shoulders, which at this time are held by visual inspection to within 0.005 in. The spline, being only rough-cut, is not inspected until after the operation has been finished.

When it comes from the heat-treating department the shaft is delivered to the grinding department, where one particular diameter is ground within 0.0005 in. and four other diameters are held between 0.001 and 0.002-in. limits. Each of these diameters is then inspected with Johannson gages, as well as with several other gages made especially for inspecting this part.

Additional inspection is given by a heavy block gage having two parallel plates between which the shaft is passed to ensure that the surfaces of the spline are parallel with the center line and with each other to within 0.001 in.

The length of the shaft, previously gaged visually with a profile gage to within 0.005 in., is now checked in the following manner. A fixture having a heavy gray-iron base receives the shaft in a vertical position and the 0.0005-in.-limit bearing is inserted into the bushing. As the bearing thrust shoulder seats against the bushing when the shaft is in place, a hinge plate is lowered on the opposite end of the shaft, which must register within 0.005-in. limits on the hardened flush-pin.

The root diameter of the spline shaft is finished in the hobbing operation and is held to a limit of 0.001 in. It is checked by spline ring-gages in which ample clearance has been allowed for all splines, so that the only point of

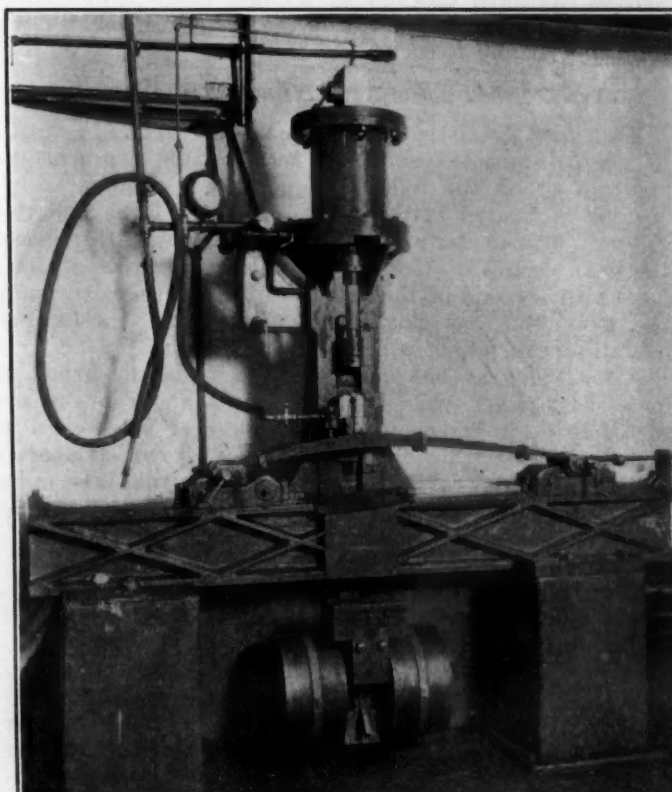

FIG. 9—INSPECTION OF CHASSIS SPRINGS
A Dead Weight Varying from 300 to 700 Lb., Depending upon the Type of Spring under Test, Is Raised by Compressed Air and Is Hung upon the Spring, Depressing It from the Position Shown in Fig. 8 to That Shown in Fig. 9. In Either Its Free or Its Depressed Position, the Spring Must Not Vary from the Standard by More Than 1/8 In.

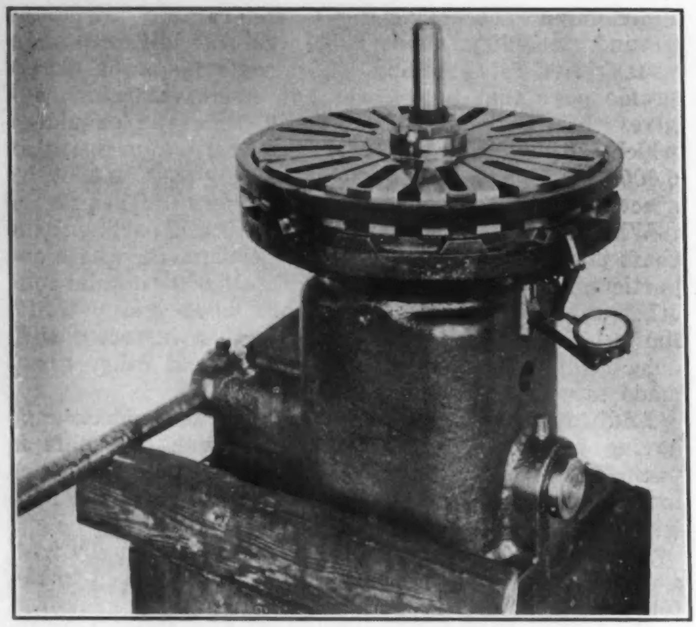

FIG. 10—TESTING THE INSIDE DIAMETER OF STEEL FLYWHEEL RINGS
The Fixture Is Made with a Base, a Sub-Base and an Expanding Top Consisting of 12 Segments Dovetailing into the Sub-Base. A Lever Having a 2 to 1 Ratio and Fastened to the Base of the Fixture Operates an Indicator Giving Readings in Thousandths of an Inch. The Segments Have Steps of Different Radii To Accommodate Rings of Various Sizes

contact that the gage makes is at the root of the shaft.

In order that the inspector may start the gages freely upon the shaft, a section of the gage one-half its length is made 0.003 in. oversize. The pitch diameters of the splines are then checked by go and no-go spline ring-gages that cover the form of the spline as well as the diameter of the fixture.

TRANSMISSION COUNTER THREE-GEAR FORGING

This gear, being one of the most important in the train of gears in the transmission, receives 100 per cent inspection of all the following operations. The first inspector is located between the automatic lathe and the Fellows gear-shaping machine department. He places the gear vertically upon a stub arbor and drops a ring-gage over the end of the arbor, which protrudes through the gear and has flush-pin limits. This checks the overall length, which is held within 0.005 in.

After the gear has been removed from the arbor, a male block-gage, which also serves as an arbor, is inserted into the same hole. This arbor or block-gage is then inserted within the centers of a Brown & Sharpe indicating center where all three gear blanks are indicated for eccentricity, the allowable limit of which on the outside diameter of any of the three blanks is 0.004 in.

The side faces of the gear blanks from which the teeth are cut are held to a maximum eccentricity of 0.002 in. Profile gages locate each blank upon the barrel, as well as the undercut chamfers and spacing.

After the gear has passed through the teeth-cutting operations, an inspector places it upon specially constructed indicating stanchions where the pitch diameter is checked for eccentricity by rolling the gear against hardened master gears. During this operation the inspector, while rolling the gears with his hands, leans the weight of his body against an extended arm that carries a movable center, and applies the desired amount of pressure at the contact-point.

Any teeth that may be high or low or that have been burned by the cutter are instantly indicated on an Ames tooth-indicator. The maximum eccentricity allowed on any of the three blanks is 0.003 in.

Another inspector then measures the pitch diameter of each blank by using two 0.25-in. hardened pieces of rod, drilled through their centers to permit their being fastened to the ends of a piece of piano wire. The piano wire resembles a horseshoe in shape with a hardened pin attached to each end. The tension of the piano wire holds the wire between the teeth of the gear while the inspector with a micrometer measures the distance over each pin as the pin rests upon the pitch diameter.

The gear is then heat-treated and hardened, after which a flanged bronze bushing is assembled at either end, and an inspector checks the overall length of the gear from the finished faces of the bushing.

The pilot, on which the fourth gear is mounted, is indicated between horizontal centers, to ensure that the fourth gear will run through with the three gears that are integral with one another. If the pilot is found to be 0.002 in. eccentric, a chalk mark is placed on the low side and this side is assembled with the high side of a fourth gear that has been correspondingly marked before being assembled.

TRANSMISSION CASE

The first inspector that handles the transmission case receives it when the bell or flange end only has been

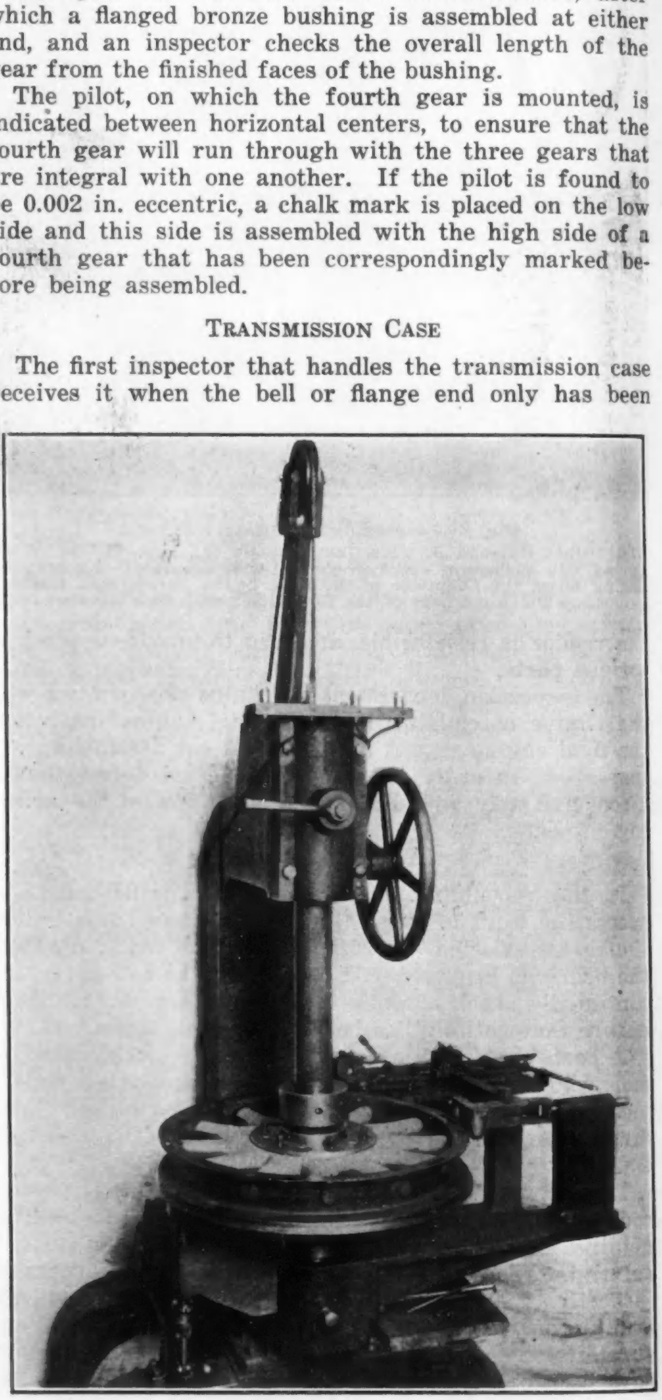

FIG. 11—INSPECTION OF WHEELS AND BRAKE-DRUMS
A Check of the Radial and Lateral Runout of Both the Wheel and the Brake-Drum Is Made Simultaneously by a Series of Reduction Levers and Four 2-Cp. Incandescent Lamps So Arranged That if the Tolerance of Any One of These Four Features Exceeds a Specified Amount an Electrical Contact Causes the Corresponding Lamp To Become Lighted. If the Tolerance Is Not Exceeded the Lamps Remain Unlighted

completely machined. The vertical standard for the $3\frac{1}{2}$-in. vertical arbor is used by slipping the case over the arbor, giving practically a ring fit. The end of the arbor is bored to receive an indicating-arm that carries two Ames indicators. This arm, having been placed in the pilot hole in the arbor, is turned around by the inspector, one indictor checking the eccentricity of the face of the flange, the other the eccentricity of the pilot. The maximum amounts of eccentricity allowed at these two points are 0.005 and 0.007 in. respectively.

The next inspector receives the case at the foot of a conveyor after the case has been completely finished. Here a block-gage checks each of the reamed holes, a peculiarity of these gages being that they are on both the go and no-go ends and are of $\frac{3}{4}$ or 1-in. radius, instead of being of the straight or square-cornered type, measuring to the blueprint size across the arc of the bar only. This allows the entering and checking of sections of the holes that might be large, whereas the same holes might be of the correct size at each end.

Strict visual inspection is required for sand holes and cracks, the case being tapped with a metal mallet to ascertain by sound whether it contains any cracks too small to be seen.

Differential Carriers

Careful inspection is made of the differential carriers. First, the holes are inspected with go and no-go gages, then are checked for the depth of the sleeve bearing, the diameter of the counterbore, the location of the faces with respect to the lugs, the ring diameters, the clearance for the housing, and the flush-pin depth from the pinion to the face of the carrier. The bearings are then plugged with go and no-go gages.

In determining the alignment of the differential bearing with the pinion bearing a special fixture is used, which is shown in Fig. 5. Two hardened collars *A*, representing the differential bearings, are placed in the carrier in their proper positions. Test bar *B* is hardened and ground to fit the collars *A* with 0.0002-in. clearance. The straightness of the test bar is maintained within 0.001 in. throughout its length of 16 in. When the bar is assembled in the collars and the carrier is set down on the hardened ground-steel stud *C* that is mounted in the cast-iron plate *D*, the test bar comes to rest on the stud *C* and the carrier is swung around to take a reading of the position of the pinion relatively to the gear. The test bar comes to rest against a solid stop, not shown. The horizontal micrometer-head is first brought against the bar and the reading taken, then another reading is taken with the micrometer in a vertical position. After rotating the carrier 180 deg., readings are again taken, the difference between the end readings giving the error. The vertical micrometer tests the squareness of the pinion bearing with the differential bearing.

Steering-Knuckles

Inspection of the steering-knuckle is effected by a special fixture, shown in Fig. 6, which tests the angle of the king-bolt hole with the spindle bearing to produce the camber of the wheel. In this fixture, the test plug *E* of hardened steel with a ground surface is inserted through the two bearings *FF* supported in a swivel yoke, which has its center under the center of the king-bolt, and at the same time is inserted through the bearing of the king-bolt in the knuckle.

Center points *GG* are then engaged to bring the steering-knuckle to the center of the fixture. Extending under the spindle is an indicating arm *H* that comes to rest when the steering-knuckle is in the fixture. A graduated section *I* at the end of the indicating arm is easily read because of its large graduation and shows instantly the relation of the king-bolt to the spindle bearings.

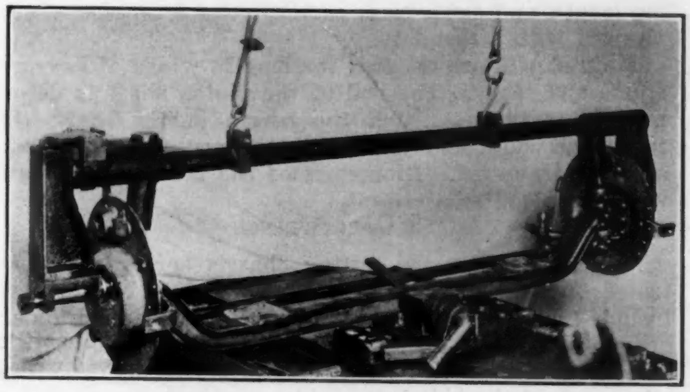

Fig. 12—Inspection of Toe-In of Front Axles
The Tie-Rod Must Be Adjusted To Make the Axle Fit the Fixture, Which Shows the Amount of Toe-In Necessary

Universal-Joint Yokes

An interesting fixture that is shown in Fig. 7 is used to test the centers of universal-joint yokes for being central with the spline hole and also to show whether the centers are at right-angles with the center-line. This is accomplished in the following manner.

The splined bushing *J* is inserted into the splined hole in the yoke, being a light drive fit. Arbor *K* is then pushed through the bushing, holding the yoke to be inspected in a horizontal position, but allowing it to oscillate and also to slide on the arbor. Compressed air is then admitted to the air-cylinder *L* through the two-way air-valve *M*, forcing the equalizing centers *NN* into the centers of the yoke and raising or lowering the casting *O*, which, in turn, checks the yoke for off-center and also turns it on the trunnion *P*, to check the 90-deg. angles. The casting *O* is connected with two multiplying-levers *QQ* that make electrical contact *R*, lighting the lamp *S* if the work is off the center-line more than the tolerance, or the lamp *T* if off on the angles. If off both ways, both lamps are lighted. Valve *U* operates two jets of air for cleaning the centers of the fixtures. Tolerances may be set for any requirements by adjusting the contacts *RR*. This fixture operates at the rate of 200 yokes per hour and all yokes are given 100 per cent inspection.

In I-beam axles, the inspection covers the size of the king-bolt holes, the parallelism of the spring-pads, the relation of the lock-bolt holes to the king-bolt holes, and

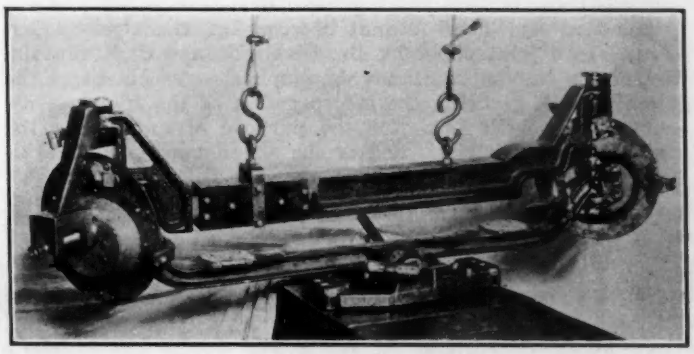

Fig. 13—Checking the Camber of the Front Axle
This Fixture Checks the Angle of the Front Axle Necessary To Get the Proper Turning-Radius

the length and squareness of the latter. Clip holes are checked with a template.

Main shafts are checked for length, width of keyway, spline and taper. The roll of the pinion shaft is determined for trueness, and the length of the shaft, the taper, the width and depth of the keyway, and the spline are also inspected. Diameters of the bearings are held within 0.0005 in.

CHASSIS SPRINGS

A special device for testing chassis springs is illustrated in Figs. 8 and 9. The points covered by this test include the free height of the spring, its deflection under normal load, the width between the spring eyes, the diameter of the hole in the spring-bolt bushing, and the alignment of the bolt holes with one another.

A dead weight varying from 300 to 700 lb., depending upon the type of spring under test, is raised by compressed air and is hung upon the spring, depressing it from the position shown in Fig. 8 to that shown in Fig. 9. In either its free or its depressed position the spring must not vary from the standard by more than 1/8 in.

STEEL FLYWHEEL RINGS

The fixture shown in Fig. 10 for testing 14-in. steel flywheel rings is composed of three parts: a base, a sub-base, and an expanding top, consisting of 12 segments or movable parts dovetailed on the lower side to fit into other dovetails cut in the sub-base. Only six dovetails are cut in the sub-base, the remaining six being held in place by cap-screws to take up wear. In each segment a slot is milled to accommodate a spring that holds the segment against the expander, which is dodecagonal in shape, tapered, and is pulled down by a connecting-rod and cam on a shaft operated from one side of the fixture.

As the expander has 12 sides, the same number as that of the segments, and both have the same taper, a true bearing on the segments is obtained at all places where expansion takes place and the fixture has a perfect outside diameter. A 2 to 1-ratio lever is fastened to the base of the fixture, the short arm resting on the segment, the long arm operating an indicator that gives exact readings in thousandths of an inch. The indicator is adjusted for a steel ring approximately 14 in. in diameter, but the segments have steps of different radii to accommodate rings of various sizes.

WHEELS AND BRAKE-DRUMS

Fig. 11 shows a special machine for checking the radial and lateral runout of both the wheel and the brake-drum simultaneously by a series of reduction levers and four 2-cp. incandescent lamps. All four of these points can be checked at one revolution of the wheel, for the levers are so arranged that if the tolerance of any one of these features exceeds a specified amount, an electrical contact is made that causes the corresponding lamp to become lighted. If the tolerance is not exceeded, the lamps remain unlighted.

Fig. 12 shows the method of checking the toe-in of the front axle. Limits on the fixture shown are positive. The tie-rod must be adjusted to make the axle fit the fixture, which shows the amount of toe-in necessary. Fig. 13 shows the method of checking the angle on the front axles to get the proper turning-radius.

MEETINGS OF THE SOCIETY

(*Concluded from p. 316*)

onstration, with conveyance of the visiting party from Philadelphia to Aberdeen, Md., by gasoline rail-car and trailer over the Pennsylvania or the Baltimore & Ohio Railroad.

SAFETY DRIVING RULE DISCUSSED

Washington Section Considers Enforcement of Clear-Course-Ahead Law

The subject of the evening at the new season's first meeting of the Washington Section, held at the Cosmos Club, City of Washington, on Sept. 11, was Dr. H. C. Dickinson's proposed single safe driving rule, first announced and explained at the Semi-Annual Meeting of the Society last June. In a joint paper by Dr. Dickinson and C. F. Marvin, Jr., of the Bureau of Standards, emphasis was placed on the possibility of securing the incorporation of the rule in present motor vehicle laws for the purpose of amplifying the term "reckless driving" and of the abandonment of all arbitrary speed and brake regulations. The rule reads:

No vehicle shall be operated at a speed such that it cannot be stopped within the assured clear course ahead.

Discussion centered upon the possibility of enforcement of a law based on this rule. M. O. Eldridge, traffic director of the City of Washington, and other members of the traffic force took part in the debate. All of the speakers agreed that, as a principle of driving, the clear-course-ahead rule was admirably adapted for all conditions, but opinions differed on the question of its enforcement as a law and the securing of convictions under it. Of the 30 members and guests present at the meeting, a large proportion had ideas to offer.

S. W. Sparrow, chairman of the section, opened the meeting with an announcement of the appointment of standing committee chairmen for the season as follows: Entertainment, J. O. Eisinger; Publicity, C. H. Warrington; Membership, A. W. S. Herrington; and Meetings, R. M. Parsons.

The probable date of the next meeting, as reported by Secretary Robert F. Kohr, is Oct. 23, the evening preceding the next automobile race at the Baltimore-Washington speedway. Efforts are being made to secure a speaker on some subject pertaining to the building of racing cars.

Vol. XVII October, 1925 No. 4

An Analysis of Machine-Tool Maintenance

By A. R. Kelso[1]

Production Meeting Paper

ABSTRACT

MACHINE-REPAIR analysis and a criticism of present-day equipment, with analytical tables based on data collected from a 5 months' study, are followed by conclusions relative to the reliability of present-day equipment. Eight types of common machine-tools are considered and the maintenance advantage of one over the other is deduced from the consolidated tables based on monthly reports. A comparison of each class of machine-tools with the others is made, as well as a summary of the weaknesses of each class from the frequency of repairs of the elementary parts. The attention of the builders is drawn to the conditions that the shop encounters with their equipment.

A maintenance budget-system is described that has been installed in one plant to give the men a comparative idea of particular equipment that is running in excess of the budget time. It also serves in lieu of an inspection of the conditions of the equipment and is an indication of the time when overhauling is advisable. The analysis shows that a few makes of machine predominate in each group which can serve profitably as a basis for standardization. The other makes, in comparison, are not giving the same return on the investment, because of the expense charges and the loss of time for maintenance.

ORDINARILY considered as a generality only, the maintenance of machine-tools brings to light some startling details when analyzed. The frequency of repair is too high and the repair time required per month for each machine is too great, for machine-tools in general. The combining of sales points and fundamental principles so as not to sacrifice one to get the other, constitutes good design. Unfortunately, due to the drive for modifications, the need for improving the existing fundamentals has been lost sight of and the reliability that should exist has not yet been attained. A machine is a manufacturing unit and produces a profit comparable with the general earnings of the group of which it forms a part.

The largest single expense item that concerns the machine is that due to maintenance and lost time. Ordinarily, only the productivity of the machine is the measure of its worth, but if productivity is not realized for a large percentage of the operating time and if, when the machine is out of service, it is piling up repair expense, then its sales points of advantage, when compared with a somewhat slower and more reliable machine, become of somewhat doubtful value. This paper deals first with the analysis from the repair and maintenance viewpoint, with the purpose of showing by records in what ways machines would be better if they were narrowed down to a few types; second, with the general conditions of machines, so far as their operating efficiency goes, as developed over a period of time, showing also the general weakness found in the machines; and third, with the necessity for keeping equipment in first-class condition if the cost of repair is to be kept down. The second part of the paper deals also with a method of budgeting an allowance for repair and maintenance based on the cost of the machine.

Reports as to condition of equipment and the relative amount spent on each machine places the foreman in each department on a basis comparable with that of other foremen. In analyzing maintenance, the data collected afford a good basis for judging the operating efficiency that can be expected of each class of machines. An assumption is made that all machines of the same type produce equally but, in the last analysis, weight must be given to the relative productivity and the accuracy and the quality of work that the machines produce before a final disposition can be made. We will consider the following 10 classifications: Grinding machines of the centerless, the external, the internal and the surface-grinding types; automatic screw-cutting machines; horizontal and vertical milling-machines; gear-cutting machines; multiple-spindle vertical drilling-machines; and turret lathes.

Method of Analysis

The method of analyzing the repairs was to obtain the machine number, the item to be repaired and the hours spent in repairing from the repair ticket. The data were summarized at the end of the month in regard to the percentage of the total number of machines that were repaired, the total hours spent in repairing, the total hours spent in repair per machine, the percentage of repairs according to the elements of the machine and a determination of what machine predominated. Before this was begun, however, several months were spent in getting the equipment into the best possible condition.

More than 300 grinding machines, of 24 different makes, were considered. Not all are included herein because, where only a few of one kind were analyzed, a prejudiced analysis might result unless it were carried over a long period. Table 1 gives the figures on the four predominating types. An attempt to use figures was made only on those types for which the percentage did not become affected by one or two chronic machines. The first item of note is that, for grinding machines in general, 60 per cent had to be dismantled for repair every month for an average repair time of 6½ hr. The figures are for all grinding machines but, when computing Table 1, it was found that the machines listed were indicative of the entire number.

As to the comparison of the performance of makes of machine, let us consider the external grinding machines when nearly an equal number of both makes and enough machines of each make are provided. Machine *D* has 0.92 hr. less repair per machine than does machine *C* or, for the total number of machines, 71.76 hr. less repair time per month, it being understood that the hours not spent for repair are spent in production. The figures on the internal grinding machines are not truly com-

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TABLE 1—ANALYSIS OF MACHINE REPAIR

Kind of Machine	Make or Type	Total Number of Machines in Use	Frequency,[2] Per Cent	Average Extent,[3] Hr.
Grinding				
	Centerless *A*	6	81.4	13.51
	B	10	65.6	6.93
	External *C*	69	63.6	8.28
	D	78	65.0	7.36
	Internal *E*	16	63.5	3.64
	F	19	64.0	4.45
	G	25	77.0	8.94
	Surface *H*	8	20.0	1.24
	J	9	38.0	2.46
	K	13	75.0	8.39
	Average	253	61.4	6.52
Automatic Screw-Cutting				
	L	9	77.4	7.96
	M	56	51.0	5.91
	N	65	65.0	6.54
	Average	130	64.5	6.80
Horizontal Milling				
	Ra	29	46.0	3.07
	Rb	10	46.0	2.73
	Rc	15	51.8	4.31
	S	15	48.0	2.27
	T	7	21.0	2.41
	U	10	30.0	2.38
	V	19	30.0	2.72
	Average	105	38.9	2.84
Vertical Milling				
	AA	3	6.6	1.27
	AB	11	47.0	3.50
	AC	3	33.3	5.63
	AD	3	6.0	0.10
	AE	23	30.0	4.30
	AF	3	26.0	3.23
	Average	46	24.8	3.00
Gear Cutting				
	BA	100	18.0	0.125
	BB	63	47.0	2.050
	BC	15	58.0	3.820
	BD	97	58.0	3.580
	Average	275	45.2	2.394
Multi-Spindle Vertical Drilling				
	CA	41	67.0	11.30
	CB	28	71.0	8.09
	CC	8	72.4	10.58
	Average	77	70.0	10.00
Turret Lathes				
	DA	15	40.0	2.73
	DB	14	74.0	21.05
	DC	9	62.5	2.94
	DD	69	61.2	4.88
	DE	12	70.0	5.77
	DF	138	42.4	3.41
	Average	257	58.3	6.89
Single-Spindle Drilling				
	EA	12	35.3	0.88
	EB	18	32.0	0.82
	EC	67	18.0	0.66
	ED	11	18.0	0.68
	EF	46	39.0	1.29
	EG	36	50.0	4.63
	EH	80	39.2	2.83
	EI	24	31.4	2.35
	EJ	15	26.7	2.31
	Average	309	32.2	1.83
Two-Spindle Drilling				
	FA	22	28.00	0.88
	FB	14	24.80	1.45
	FC	15	41.50	4.63
	Average	51	31.40	2.32
Three-Spindle Drilling				
	GA	15	29.00	0.78
	GB	10	35.00	3.13
	Average	25	32.00	2.95
Four-Spindle Drilling				
	HA	6	51.30	4.53
	HB	8	72.00	5.36
	HC	5	20.00	0.61
	Average	19	47.80	3.50
Six-Spindle Drilling				
	JA	8	65.50	11.85
	JB	5	40.00	1.94
	JC	5	80.06	9.16
	Average	18	61.80	7.68

[2] Frequency is defined as the average percentage of the number of machines in use that are taken down for any repair during the month.

[3] Extent is defined as the average total time spent on repair divided by the total number of machines.

parable, as too great a difference exists between the capacity of the machines. However, the figures are valuable, as they indicate the need that machine-tool builders devote more attention to the reliability factor of their machines.

The centerless grinding-machine figures in Table 1 show that machine *A* is considerably different from machine *B*. The extent of repairs for each Type-*A* machine in use is nearly double that for Type *B*. If we divide the extent per machine by the frequency, it is found that the average repair time for a dismantled machine was 16.60 hr. for Type *A*, and 10.55 hr. for Type *B*, showing that it is difficult to gain access to the vulnerable parts of centerless grinding-machines.

Automatic screw-cutting machines have nearly the

TABLE 2—CHIEF CAUSES OF REPAIR TO VARIOUS TYPES OF MACHINE EXPRESSED AS A PERCENTAGE OF TOTAL REPAIRS

Machine Part	Grinding	Automatic Screw-Cutting	Horizontal Milling	Vertical Milling	Gear-Cutting	Multiple-Spindle Vertical Drilling	Turret Lathes	Drilling
Spindle and Bearings	35	7.0	15.0	9.7	28.0	48.2	7.00	25.40
Feed Mechanism	15	35.0	30.0	40.2	21.0	16.0	19.70	14.75
Main Drive	8	8.0	5.6	24.1	7.5	12.0	9.60	34.50
Pump	6	6.5	10.6	2.0	12.2	1.8	4.20	5.50
Clutch	4	6.0	12.0	3.0	2.5	...	6.00	....
Work Head or Table	6	...	3.0	2.6	4.6	...	....	....
Overhauling	7	...	9.4	...	5.0	...	12.00	....
Chuck	...	9.0	...	...	...	...	....	....
Cross Slide	...	3.0	...	...	...	...	....	....
Bearings	...	2.0	...	...	...	1.4	3.00	....
Index	...	...	...	6.5	...	...	....	....
Cable or Chain	...	...	...	...	...	12.0	....	....
Turret	...	...	...	...	...	...	14.84	....
Air Chucks	...	...	...	...	...	...	8.80	....

same frequency of repair as grinding machines. A marked difference exists between the repairs here: 26.4 per cent between Types *L* and *M*, and 14.0 per cent between Types *M* and *N*. When the Type-*M* machine needs to be dismantled for repair, it is out of service for a considerable length of time; hence, the extent of repairs per machine, only 0.63 hr., does not show such a marked difference.

Analysis Table 2, showing the chief causes for repair, indicates that the predominating repair is due to the feed mechanism. When analyzed, the Type-*N* machine is found to be the worst offender. This is an instance in which the frequency of repair is more annoying than the extent and, apparently, greater attention on the part of the builders of the machine would correct much of the trouble. In the case of automatic lathes, if the extent of repair is divided by the frequency, it will be found that the Type-*N* machine is 14 per cent lower than the Type-*M* machine.

Horizontal milling-machines enter the class of machines in which ruggedness is more developed. As shown in Table 1, the frequency of repair as a whole drops approximately to 30 per cent, the extent of repairs being reduced to 3 hr. per machine per month. These machines are a good criterion of what should be expected of machine tools. The first two, Types *Ra* and *Rb*, are special forms of the third, Type *Rc;* so they are disregarded temporarily and Types *Rc*, *S*, *U* and *V* are compared according to months.

Table 3 shows the consistency of the Type-*U* and the Type-*V* makes of machine very clearly and also shows another example, the Type-*S* machine, in which the frequency of repair is high but the extent of repair is low. Again referring to Table 1, with reference to the Type-*R* machines, it is noted that the frequency of repairs is about equal on all, although the extent, in hours per machine, is higher for the general machine.

With reference to the vertical milling-machines, machines *AA*, *AC*, *AD* and *AF* furnish an interesting comparison, since three machines of each make are available. Makes *AA* and *AD* are "down," or dismantled, 6 per cent of the time only, but makes *AC* and *AF* are down 33 per cent and 26 per cent respectively. Make *AB* is the same as Type *Rc* of the horizontal milling-machines, and make *AE* is the same as make *V*. The frequency of repair is about the same for *AB* and *Rc* and for *AE* and *V*, that is, in both vertical and horizontal-milling machines, although the extent of repair is reversed in the vertical milling-machines.

The four makes of gear-cutting machines furnish one of the most interesting examples. There are 100 of the *BA* machines and 97 of the *BD;* hence, one machine makes a difference of 1 per cent only and the percentage for frequency is then a true measure of the performance. A 40 per cent difference in frequency of repair and a difference of 3.455 hr. per machine in maintenance time per month is noted. With 100 machines, we have 3.455 more hours off per machine for one make than for the other every month; or, if it is considered that they were all of the one make, more than 678 hr. of additional service time per month as between one make and the other. Eliminating the *BA* machine, which is so far superior to the others, the frequency of repair is 54 per cent and the extent of repair is 3.15 hr. per machine in use. This latter figure is low, compared to machines as a whole, but it is high compared to make *BA*.

Multiple-spindle drilling-machines have a high frequency of repair due to spindle trouble, but this is rather to be expected. Turret lathes apparently should

TABLE 3—COMPARISON ACCORDING TO MONTHS OF SERVICE

Type of Machine	Number of Months	Frequency, Per Cent	Extent, Hr.
Rc	5	60	3.13
	4	53	3.75
	3	53	2.85
	2	40	6.50
	1	28	5.30
S	5	54	3.05
	4	40	2.76
	3	53	3.76
	2	33	0.83
	1	33	1.03
U	5	30	2.50
	4	20	4.10
	3	30	0.70
	2	40	1.83
	1	30	2.83
V	5	31	1.76
	4	26	1.33
	3	35	6.22
	2	37	2.40
	1	21	1.93

have a frequency of not more than 40 per cent, which brings them into the class with milling machines. The elimination of the Type-*DB* machine, which shows so poorly, would bring the extent of repair per machine down to 5.426 hr.

Vertical drilling-machines show the lowest number of hours for repair per machine of any, which is natural because it is a relatively simple machine. On the four and six-spindle machines, one make in each is outstanding and both are popular in the automotive industry.

TABLE 4—EXCESS-REPAIR TIME FOR 5 MONTHS

Machine Number	Kind of Machine	Duration, Number of Months	Excess Repair, Hr.
2—4	Double-End Press	1	0.00
		2	4.75
		3	11.50
		4	12.50
		5	30.25
2—6	Turret Lathe	1	10.75
		2	0.00
		3	7.00
		4	18.50
		5	24.50
2—7	Multiple-Spindle Drilling Machine	1	19.00
		2	14.10
		3	2.10
		4	14.80
		5	24.50
2—9	Riveting Hammer	1	0.00
		2	29.15
		3	42.40
		4	5.20
		5	30.50
2—5	Turret Lathe	1	19.00
		2	12.50
		3	11.00
		4	2.75
		5	18.25
6—2	Turret Lathe	1	14.75
		2	10.65
		3	20.25
		4	0.00
		5	0.00
5—5	Crank Grinding Machine	1	8.75
		2	21.75
		3	43.00
		4	4.00
		5	38.50
1—2	Crank Grinding Machine	1	0.00
		2	13.80
		3	0.00
		4	6.00
		5	0.00

Table 2, showing the chief causes for repair over the period, gives an idea of the prevalent weakness in each class of machines. Spindle and spindle bearings, and feed, are the greatest repair items, the main drive and the clutch are next and pump trouble comes in for a far larger share than is its due, probably because it is given so little attention. Better design and the use of strainers would eliminate most of this trouble.

Cost of Machine Repair and Maintenance

To focus attention on machine-repair costs and care of the equipment a plan was put into operation based on the assumption that a certain limited amount of machine repair is necessary and legitimate. This amount of repair time was worked out on a basis of 4 hr. per month for every $1,000 initial cost of the machine. A list was furnished each month to the foreman, giving the number of the machines that exceeded their repair budget. An analysis of these reports gives the information that is lacking in the first general analysis; that is, what particular machines are causing the high upkeep, if any specific ones do so. This analysis shows also any machine that is in such bad shape that it should be removed from service until it is put in first-class condition.

Referring to Table 4, which is a list selected from some of the machines to illustrate the point to be brought out, it gives the figures of excess-repair time spent on certain machines over a period of 5 months. Machine No. 2-4 is an example of how the excess increases as the general condition of the machine becomes worse. Apparently, a proper repair has not been made or the machine needs a general overhauling. If all the machines of the same kind appeared on the list, it might indicate that the budget was wrong; but, where only one or two machines reappear repeatedly, it centers the cause specifically. Machines Nos. 5-5 and 1-2 are of the same make and type; the former machine requires twice the average amount of time of 10 hr. shown in Table 1 of grinding machines and, after appearing on the excess-maintenance list every month, shows no sign of improvement. The latter machine shows a more common case in which a repair is made and then the machine functions normally again.

If a machine appears on the excess-repair sheet for 3 successive months with an excess figure of twice the budget time, then it would be better to spend a considerable sum in one lump for thorough rebuilding rather than to drag the process out. Generally speaking, a complete overhauling amounts to one-half the original cost of the machine. For example, if we consider a machine valued at $4,500, it would cost $2,250 for rebuilding and, of this amount, $1,125 would be spent for labor and material if overhead is figured at 100 per cent. If labor and material are figured as equal; which was found to be the case over a period of time, with labor at $1 per hr., then 527.5 hr. must be spent on the machine. If this is spent over a period of 6 months it is 87.8 hr. per month minus the budget time of 18 hr. per month; therefore, it amounts to a 60-hr. per month excess, or a little better than three times the budget hours. If this continues for 3 months, one-half of the cost of a complete rebuilding has already been spent; so, an excess of twice the budget time gives a more economical figure as a guide if the cost of overhauling is not to be spent within 6 months on maintenance.

I realize that many factors enter into machine maintenance such as the machine load, the care of the operator, the quality of the repairs, and the specific wear that comes from the special use. So far as the machine load affects this analysis, that is not important because every machine ought to be performing the operations for which it was designed. The purpose of the excess-repair-cost reports is to call the attention of the foreman to the care that the operator is giving the machine; it functions in place of a periodic inspection, as it puts the burden on the men who are running the machine.

Budget Allowance

The budget allowance may be criticized because it appears to handicap the more expensive machines of the same type. This can be afforded, for the additional investment required has one of two purposes, either to increase the quality or the production proportionately or to keep the maintenance uniformly low. If it were possible to do so, it would be better to base the budget on the increment of value that the machine gives the product. On the last analysis, though, this appears as the selling price of the machine and hence it is justifiable to use this as the basis. A machine purchased second-hand, if it is used with others of its kind, is handicapped because it is not allowed the same budgeted hours as a new one unless its allowance is based, not on the price paid for the machine, but on the cost when new.

The allowance of time for normal maintenance is mostly for what had best be called "adjustment." If a machine were perfect, and ideally taken care of, then it ought to be taken down for complete overhauling before it requires a multitude of parts replacements. This brings up the point of new machines, which should use but little of the budgeted time for the first year. If they appear on the excess-hours sheet, should it not be an indication of manufacturer's fault and covered by his guarantee?

The frequency of repair machines is high, as a whole, the percentages found being for grinding machines, 61.4; automatic screw-cutting machines, 64.5; horizontal milling-machines, 38.9; vertical milling-machines, 22.2; for gear-cutting machines, 45.2; multiple-spindle drilling-machines, 70.0; for turret lathes, 58.3; and for drilling machines, 32.0. It seems as though 20 per cent would not be an unreasonable index of reliability to expect of all machines. Machines for gear-cutting, milling, and drilling are in extensive use which show less than that in this analysis. All the added refinements lose their value if the machines must be nursed along all of the time. Of late, the tendency has been to come out with some added feature as a basis for sales talk, and not to correct the prevailing faults indicated by past performances.

Sheet Steel Fabrication

By Syd Smith[1]

Production Meeting Paper

Illustrated with Drawings and Photographs

ABSTRACT

ECONOMY is the watchword of the automotive industry. Under the present conditions of keen competition, the race has become a question of the "survival of the fittest." Inasmuch as the general appearance of an automobile depends mainly upon the sheet or strip steel used in its construction, the weight of which comprises from 25 to 30 per cent of the total weight of the car, and as approximately 65 per cent of the cost of a piece is in the stock, the opportunity to reduce costs by conserving the stock is obvious.

Keeping this point in mind, particular attention has been devoted to the utilization of the scrap from large pieces in the manufacture of small parts. Scale drawings are made of each size of sheet steel received at the factory and a card-index quickly gives information as to the possibility of making any new piece from scrap material. With a view to conserving every part of the material, several small pieces are welded together into such regular sized and shaped sheets as would be suitable for larger parts such as dust-pans, seat-pans, regulator-boards, and the like.

So great has been the progress within the last few years in the production of parts from sheet steel that they have largely superseded castings and forgings, particularly those used as body parts. But greater possibilities, however, still exist in this direction, even to the extent of making phaeton tops from a single sheet of welded steel.

The average cost of the finished sheet-metal parts of an automobile, including the enameling of the parts, is said to be about \$0.075 per lb. This is about the same as that of gray-iron castings, about one-half that of malleable castings, about 30 per cent less than that of forgings, and only about one-tenth that of aluminum castings. Although sheet-metal parts are on a par with iron castings when compared on a basis of the cost per pound, they make a still better showing when compared on a basis of strength cost.

To cite a concrete example and show a method of producing sheet-metal parts, the progress of several automobile parts, including the shroud, tonneau and side-rails, is followed during their fabrication, and the manner of assembling the side-rails and some minor parts into the chassis frame is described.

WE are living in an era of keen competition in the construction of automobiles. In the next few years we shall probably experience considerable tension in this direction and the industry will be reduced to a "survival of the fittest." Our best efforts therefore are being directed toward producing parts by the most economical methods possible. Inasmuch as from 25 to 30 per cent of the weight of an average passenger-car is due to the sheet or strip steel used in its construction, and as the general appearance of a car is dependent mainly upon this fabricated metal, the duty of men in our profession with regard to reducing the cost of utilizing this material cannot be exaggerated.

The greatest possibility for economy, in my opinion, lies in the conservation of stock, because approximately 65 per cent of the cost of a piece is in the stock, the remainder being labor and overhead expense. With this point in mind, about a year ago we improved our methods by making scale drawings of each size of sheet steel received at the factory, to show how scrap from the large pieces could be used to the best advantage in producing small parts. One of these drawings is shown in Fig. 1.

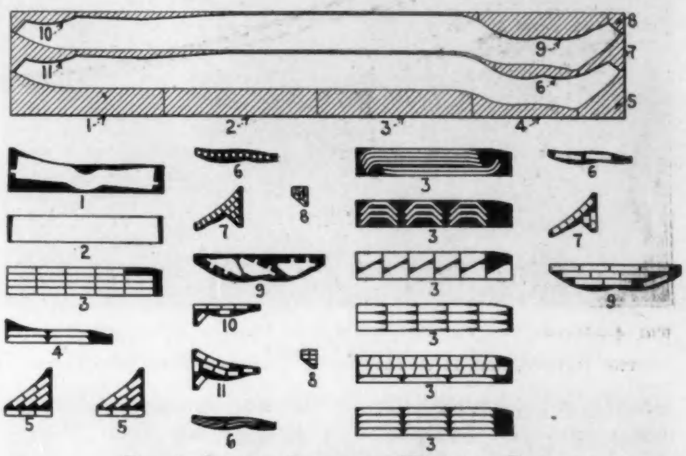

Fig. 1—Layout Sheet for Utilizing Scrap
This Drawing Shows how Scrap from Large Pieces Is Used in Producing Small Parts. A Card-Index File Indicates Quickly Whether It Is Possible To Make a New Piece from Scrap Material

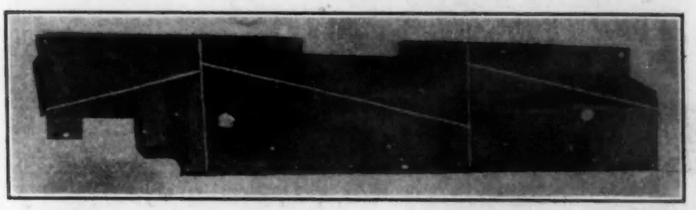

Fig. 2—A Dust-Pan Made of Scrap Pieces Welded Together. Seat-Pans and Regulator-Boards Are Similarly Made. The White Lines Indicate the Welded Joints

After this practice had been in progress for a few

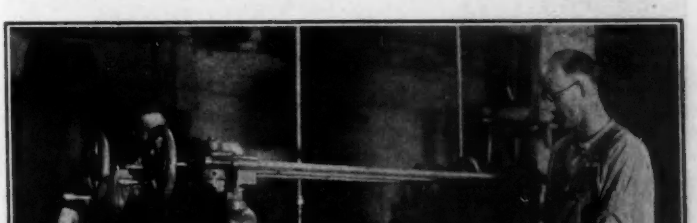

Fig. 3—Sheets Passing through a Roller Leveler
After the Stock Has Been Trimmed by a Rotary Shear into Regular Blanks, the Blanks Are Run Between Rollers To Remove Stretcher Strains

[1] Superintendent of stamping, Studebaker Corporation of America, South Bend, Ind.

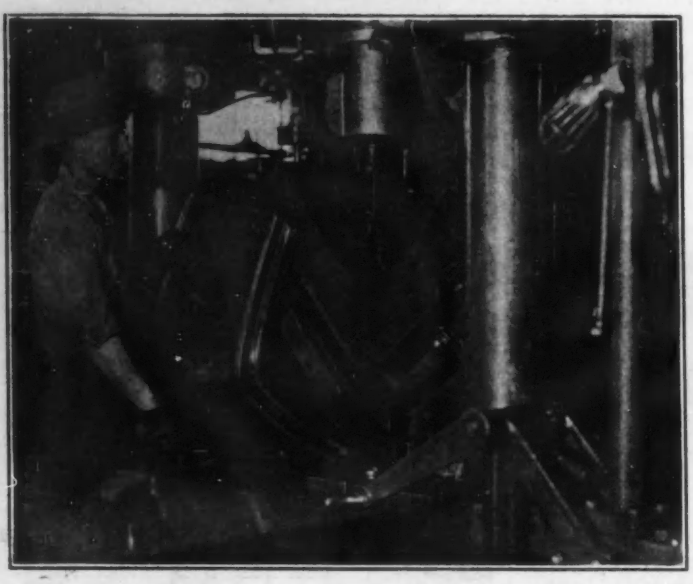

FIG. 4—HYDRAULIC PRESSES DRAW THE BLANKS INTO THE FORM OF A HALF-SHROUD
The Half-Shroud Is Shown Being Removed From the Press

months, we learned that in the average production of one month we had saved a little more than $8,000,

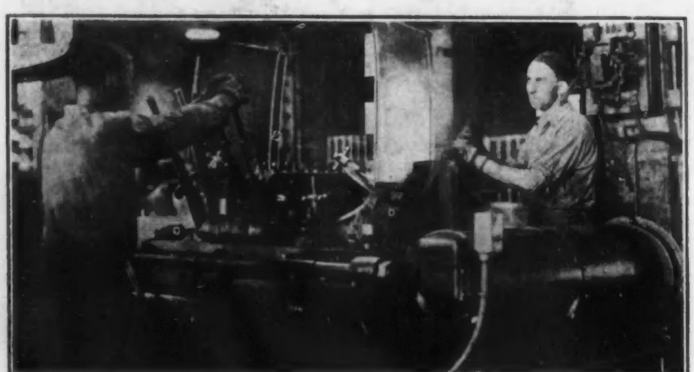

FIG. 5—BUTT-WELDING TWO HALF-SHROUDS TOGETHER
This Is the Most Modern Method of Welding Body Panels

whereas the salary of the layout man was only $200. A card-index file arranged with reference to the gages of

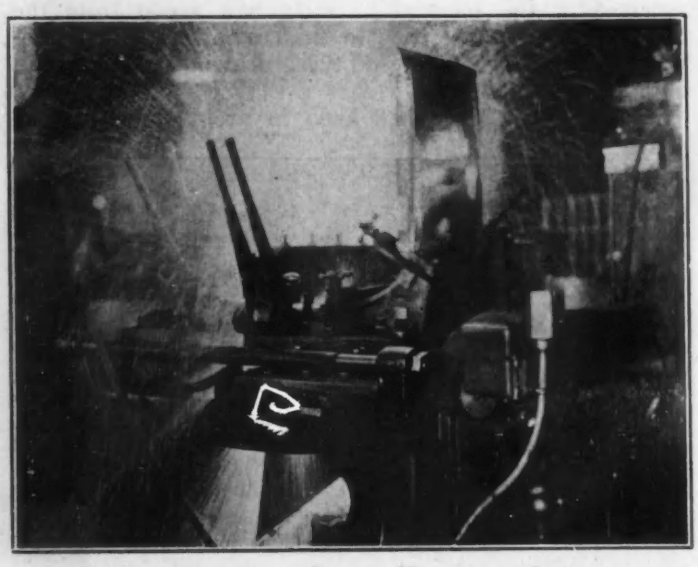

FIG. 6—SHROUD BUTT-WELDING MACHINE IN OPERATION
Contact, Lasting 8 Sec., Is Made and Broken Automatically. Alternating Current Is Transformed in Two Steps from 2500 Volts to between 7 and 9 Volts at Point of Contact. Two Machines Each Produce 40 Welds per Hour

stock informs us quickly whether it is possible to make a new piece from scrap material.

CONSERVATION OF SCRAP

In a body plant, the ratio of the small automobile parts that can be made from scrap to the larger ones is such that even though all small parts were made from

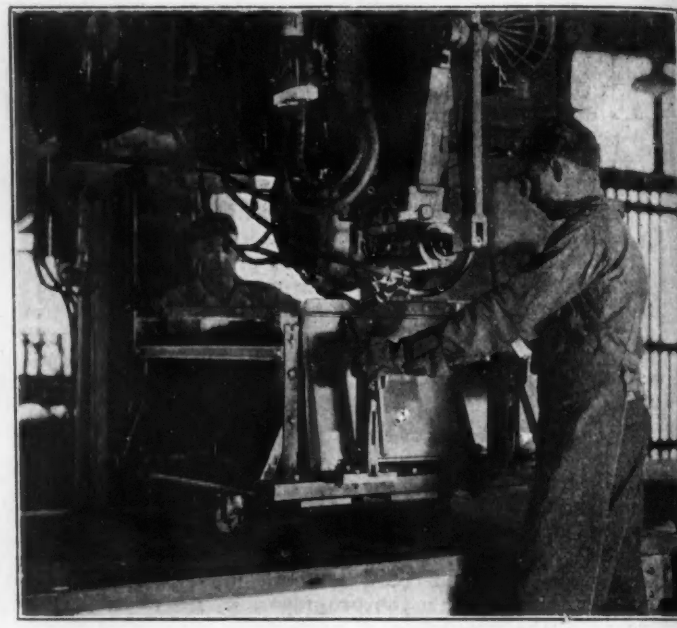

FIG. 7—SPOT-WELDING THE DASH TO THE SHROUD
A Standard Automatic Spot-Welding Machine Is Inverted and Supported Overhead

scrap, a surplus of scrap would still remain. With a view to conserving every part of this material, in the same manner that the meat packer utilizes all the parts of a hog, we are now endeavoring, by welding together small pieces, to make from No. 16 to No. 22-gage scrap

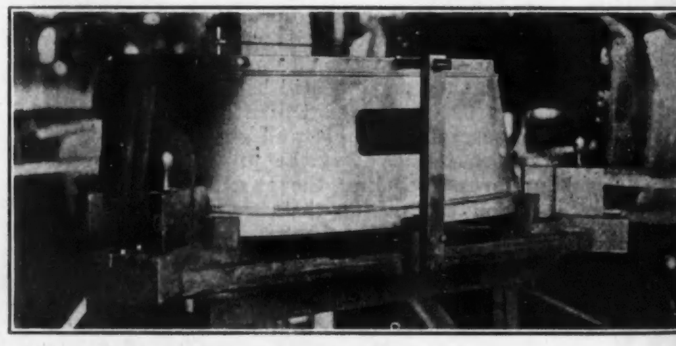

FIG. 8—INSPECTION OF THE FINISHED SHROUD
All Vital Points Are Checked by Positive Blocks and Gages

such regular sized and shaped sheets of stock as would be suitable for parts such as dust-pans, seat-pans, regulator-boards, and the like. In the dust-pan shown in Fig. 2, the white lines indicate the welded joints.

The regular blanking and minor forming operations can be performed after welding. The opportunity for economy along this line is very great; and manufacturers of equipment suitable for this kind of work should develop means of automatically feeding stock through welding machines, or welding it without feeding.

Within the last few years, wonderful progress has been made in the production of parts from sheet or strip steel that used to be made from castings and forgings, par-

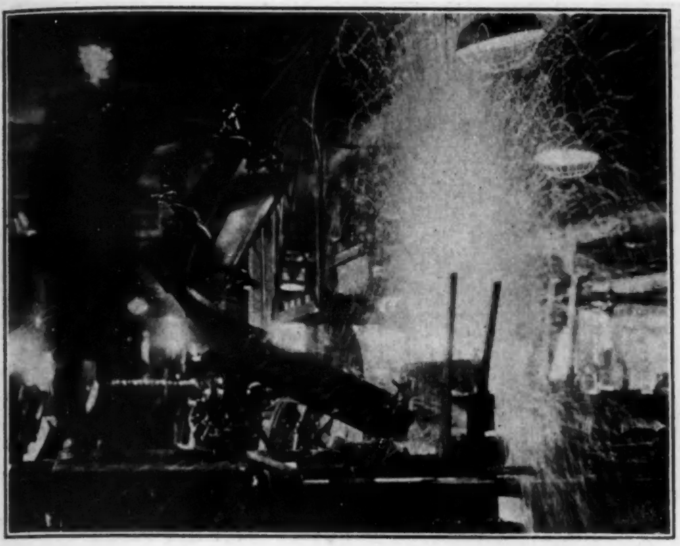

FIG. 9—WELDING THE BACK PANEL TO A SIDE PANEL
The Two Side Panels and the Back Panel Are Welded Into One Unit

ticularly body parts. Still greater possibilities exist along these lines even to the extent of making a phaeton top from a single sheet of welded steel. Such

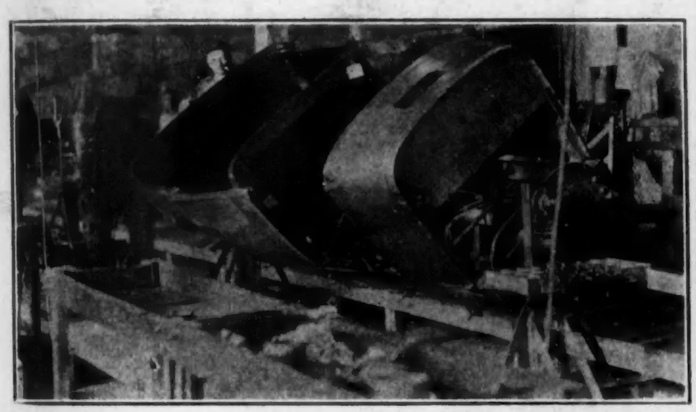

FIG. 10—REVOLVING BODY-PANELING FIXTURE ON WHEELS
Internal Finger-Clamps Operated by Screw-Shafts Running Crosswise Have Replaced C-Clamps or Bolts on These Fixtures

a top would cost about 60 per cent as much as do present fabric tops, would look better than fabric at all times, and would last as long as the body. Sounds produced by vibration can be prevented and stiffness and similar

FIG. 11—ENAMELING A PHAETON BODY
After the First Coat Has Been Flowed on, the Body Is Allowed To Drip for 20 Min., Then Is Baked for 1 Hr. 15 Min. at a Temperature of 350 Deg. Fahr. Two Succeeding Coats Are Applied in the Same Manner

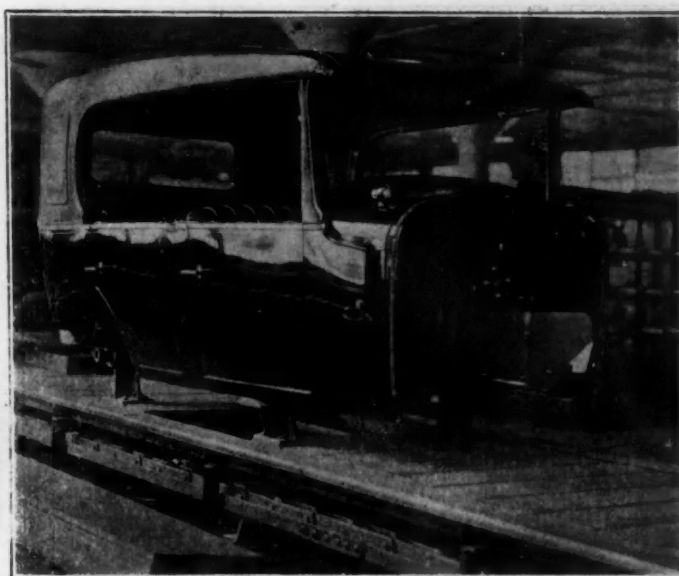

FIG. 12—PHAETON BODY WITH TOP BUILT ON
The Body Is Now Ready for the Assembling Line

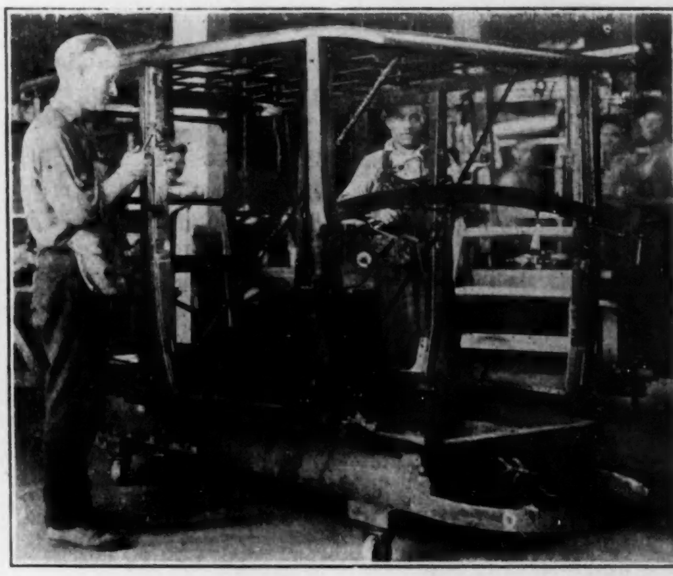

FIG. 13—ASSEMBLING OF REAR PILLAR PANEL
Frames Are Placed on Trucks on the Floor ahead of the Conveyor Line and the Rear Pillar Panel Is Assembled at This Point

FIG. 14—ASSEMBLING OF BACK PANEL

FIG. 15—ASSEMBLING OF FRONT PILLAR PANEL

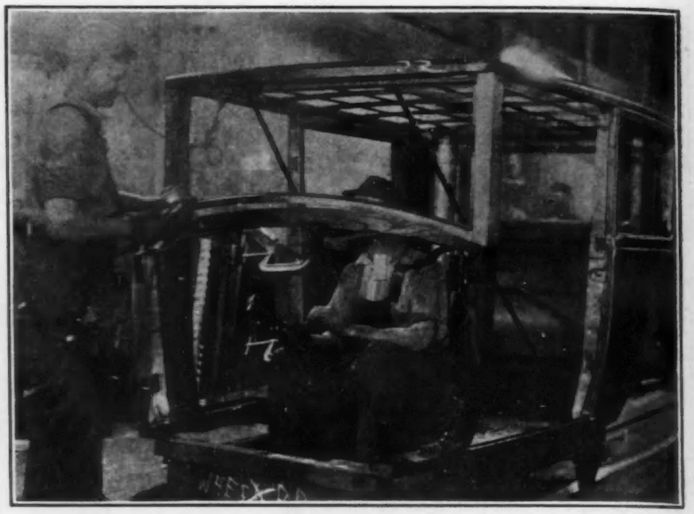

FIG. 17—ASSEMBLING OF SHROUD CROSS-BAR PANEL

qualities can be provided for by proper shaping and reinforcing. We mention this item merely as offering food for thought.

COST OF FINISHED SHEET-METAL PARTS

The average cost of the finished sheet-metal parts of an automobile, including the enameling of the various parts, is about $0.075 per lb. This is about the same as that of gray-iron castings, about one-half that of malleable castings, about 30 per cent less than that of forgings, and only about one-tenth that of aluminum castings. Although sheet-metal parts are on a par with iron castings when compared on a basis of cost per pound, they make a still better showing on a basis of strength cost.

This shows why the trend has been, and will continue to be, toward stampings and away from castings and forgings. Some years ago, stampings were considered to be of second or third-rate importance and received at-

FIG. 18—ASSEMBLING OF SHROUD
The Fit of Flanges and the Small Gap To Be Covered by the Front Molding Are Shown

FIG. 16—ASSEMBLING OF COUPE PILLAR PANEL

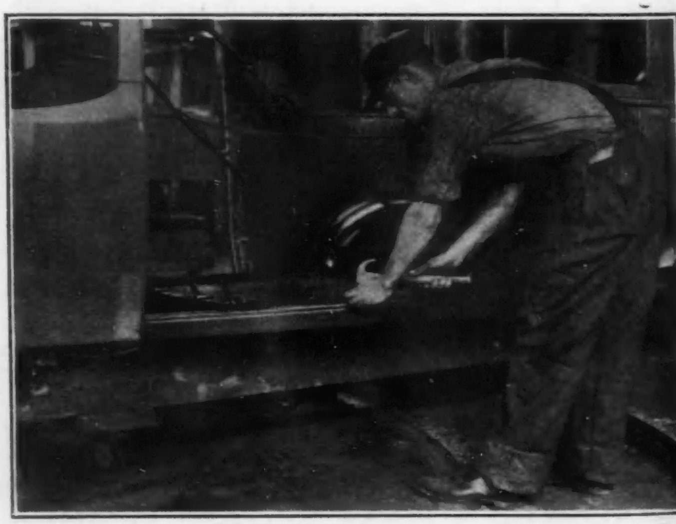

FIG. 19—ASSEMBLING OF DOOR-SILL PANEL

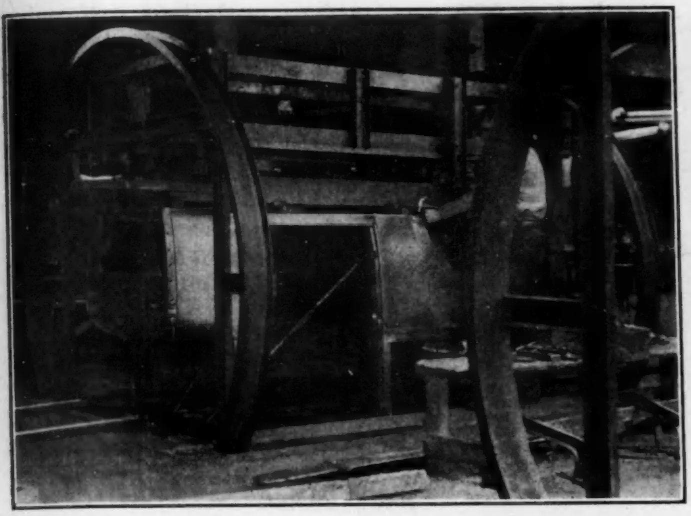

FIG. 20—REVOLVABLE FIXTURE FOR NAILING BOTTOM FLANGES
This Fixture Is Carried on Two Channeled Rims, about 10 Ft. in Diameter, That Ride on Wheels Fastened in the Floor Pit. Automatic Clamps Catch the Truck, with Body Mounted, as It Is Pushed onto the Fixture, and Hold It in the Upside-Down Position

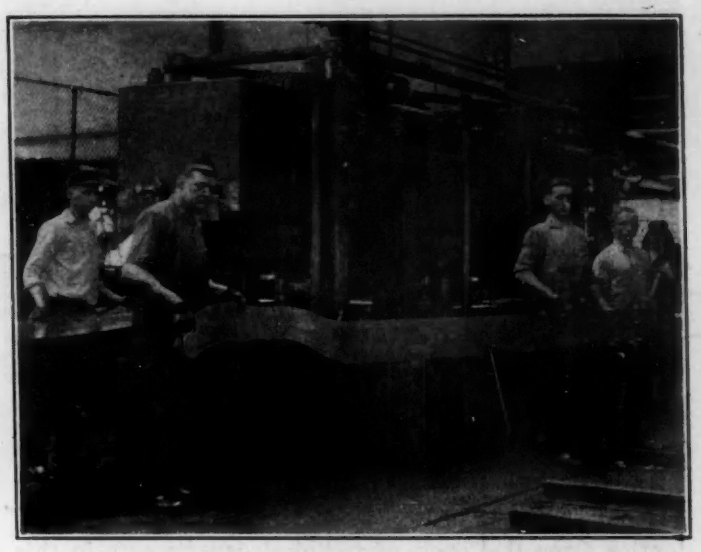

FIG. 23—FRAME SIDE-RAIL BLANKING AND FORMING PRESS
A Pressure of 1200 Tons Is Exerted by the Ram

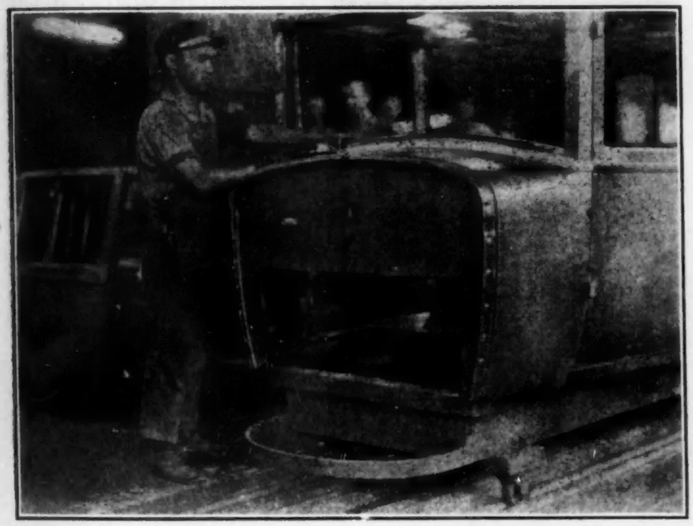

FIG. 21—ASSEMBLING OF MOLDING

FIG. 24—METHOD OF STORING SIDE-RAILS IN RACKS
Its Features Are Conservation of Floor Space and the Minimum Amount of Handling

FIG. 22—HANGING DOORS

FIG. 25—ASSEMBLING THE SPRING-HANGER CASTINGS WITH THE SIDE-RAILS
In This Operation Hot Rivets and Squeezers Are Used

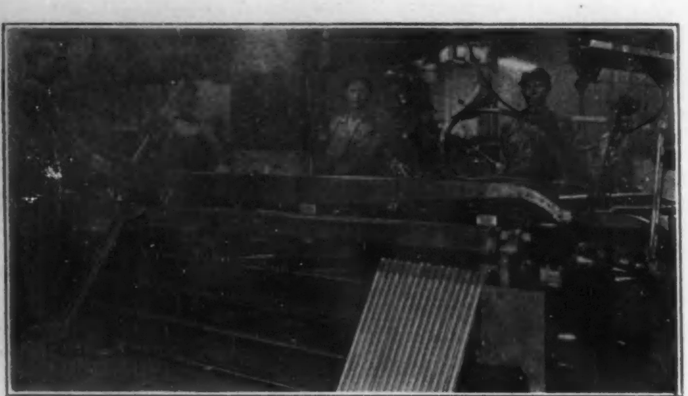

FIG. 26—PNEUMATIC FRAME-ASSEMBLING FIXTURE
Cross-Members and Gussets That Have Previously Been Made Up Into Small Assembling Units Are Assembled with the Side-Rails in One Operation. These Sub-Assemblies Include the Front and Rear Torque Cross Tubes, the Sub-Frame Assembly, and the Brake Shaft Cross Member Assembly

tention from the heads of technical departments in this proportion. Instead of being routed and processed like their cousins, they were left to find their own way through the plant. But today conditions have changed, as will be evident from some of the accompanying illustrations.

To cite a concrete example and show a method of producing sheet-metal parts, such as is typical of those in use in the plant of the Studebaker Corporation of America, the progress of several automobile parts, including the shroud, tonneau and side-rails, will be followed during their fabrication, and the manner of assembling the side-rails and some minor parts into the chassis frame will be described.

FABRICATION OF THE SHROUD

In the fabrication of the shroud, the stock is first trimmed by a rotary shear into regular blanks, which are then run between rollers, as illustrated in Fig. 3, to remove stretcher strains. In the next operation hydraulic presses, one of which is shown in Fig. 4, draw the blanks into the form of a half-shroud. The surplus metal is then trimmed off, the corners are notched with a band-saw, nail holes are pierced, and patches are put in, to fill up the notches left at the corners of the blank. The patches are welded into place with an oxyacetylene flame and, after the welding operation, the surplus steel remaining is ground off.

Two shroud halves are then butt-welded together.

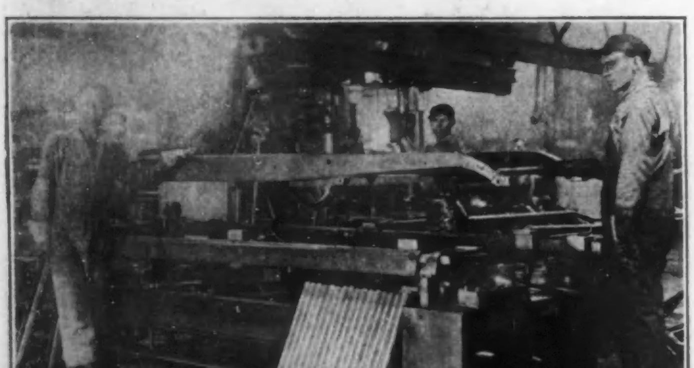

FIG. 27—ASSEMBLED FRAME BEING REMOVED FROM PNEUMATIC FIXTURE
About 80 Sec. Is Required To Squeeze the Frame Together. Four Men Assemble about 45 per Hour

Fig. 5 shows the most modern method of performing this operation. The illustration shows the manner of clamping the shroud halves into place and Fig. 6 shows the effect produced when the current is turned on. The ventilator lid opening is then punched in and formed by bending down the edges, and the reinforcement band for supporting the instrument-board is spot-welded to the shroud, as is also the dash. In welding the dash into the shroud, a standard automatic spot-welder is inverted and supported overhead, in the manner shown in Fig. 7. Holes for lacing are pierced and counter-pierced at the same time, notches on the inside of the jig indicating to the operator the points at which the holes are to be punched.

The outside of the shroud is then bumped and finished, and is inspected for both dimensions and finish, all vital points being checked by position blocks and gages, as shown in Fig. 8.

BACK PANEL

The forming and trimming of the back panel are performed in a manner similar to that of the shroud. It is trimmed and gaged to fit together with the side panels. The flange is made by sawing to a pattern and is then formed and trimmed. The two side panels go through the same process, are sawed to a pattern to match the back panel, and all three are welded into one unit, Fig. 9.

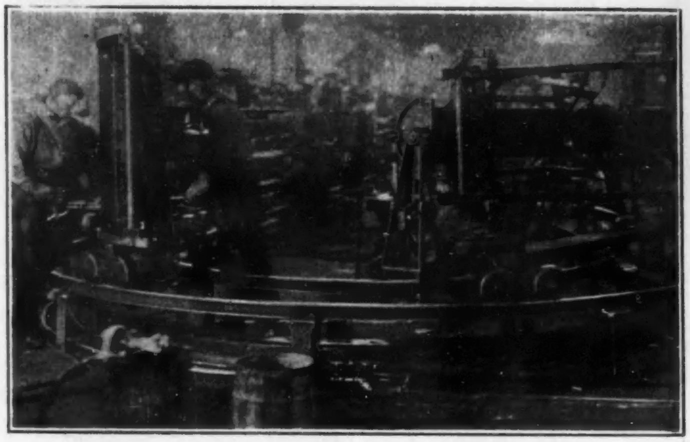

FIG. 28—FRAME IN A REVOLVABLE FIXTURE ON AN ENDLESS CONVEYOR
A Cradle Holds All the Members in Their Correct Relative Positions

Our variety of current body styles is so great that it makes the use of trimming and blanking dies prohibitive on large panels.

Holes for the fender bolts in the wheel-housing are drilled in the side panels before they are welded to the back panel. The accuracy of manufacture of the panels and sub-assemblies is maintained throughout the plant, to insure their snapping into place on the body frames on the assembling lines without any additional fitting. Into all panel assemblies is set a corner piece, the function of which is to space the panels to the proper width and prevent them from bending or spreading. Strengthening pieces are put into both the upper and lower corners of the weld.

At the present time, panels for 600 jobs per day are being finished in this department. When completed, they are put into stock and lined up for use on the assembling line. While being assembled the bodies are mounted on a special jig, by which they can readily be turned upside down during the paneling operation. In the revolvable paneling fixture, Fig. 10, internal finger clamps operated by cross shafts replace C-clamps or bolts.

Interchangeability of Doors

A very important point in the assembling of the panels is the interchangeability of the doors. Hanging the doors was formerly a high-priced operation and the work was slow; now the doors can be put on quickly by common labor and all fit perfectly without adjustment.

After the bodies come from the assembling line, they are treated with Deoxidine, washed with an alkaline solution, and rinsed with hot water preparatory to enameling. They are then sent through a drying oven to remove all moisture from the panels and the frames, and are tackragged to remove all dust.

After the first coat of enamel has been flowed on, as illustrated in Fig. 11, the body is allowed to drip for 20 min., then is baked for 1 hr. 15 min. at a temperature of 350 deg. fahr. Two succeeding coats of enamel are applied in the same manner.

When the body starts down the line, handles are put on the doors, holes are reamed for the windshield, the various trimming operations are performed, the top is built on as shown in Fig. 12, and it is now ready for the final assembling line.

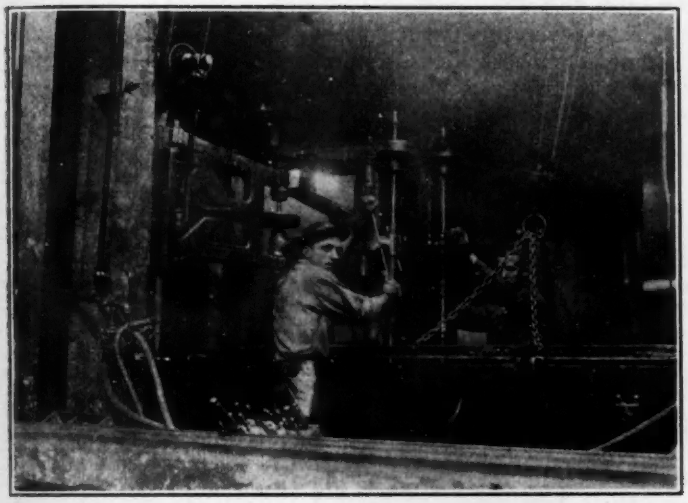

Fig. 29—Frame-Drilling Jig and Post Drilling-Machine
After the Holes Have Been Drilled in One Frame, the Jig Is Lifted from the Frame by an Electric Hoist and Is Placed on the Following Frame

The preparation of panels for our closed bodies is similar to that for the open bodies, so the details will be omitted. The welding together of the back and side panels is done on a machine considerably larger than that shown in the illustrations because the upper and lower panels are integral.

Sequence of Operations

In a Standard Six coach the sequence of assembling operations is as follows:

(1) Assembling of rear pillar panels, Fig. 13
(2) Assembling of back panel in one piece, Fig. 14
(3) Assembling of front pillar panel, Fig. 15
(4) Assembling of coupe pillar panel, Fig. 16
(5) Assembling of shroud cross-bar panel, Fig. 17
(6) Assembling of shroud, Fig. 18
(7) Assembling of door-sill panel, Fig. 19
(8) Nailing bottom flanges, Fig. 20
(9) Assembling of molding, Fig. 21
(10) Hanging doors, Fig. 22

From this point the body goes through various minor operations such as removing metal imperfections and the like, after which it is cleaned in a manner similar to that of open bodies preparatory to lacquering and trimming.

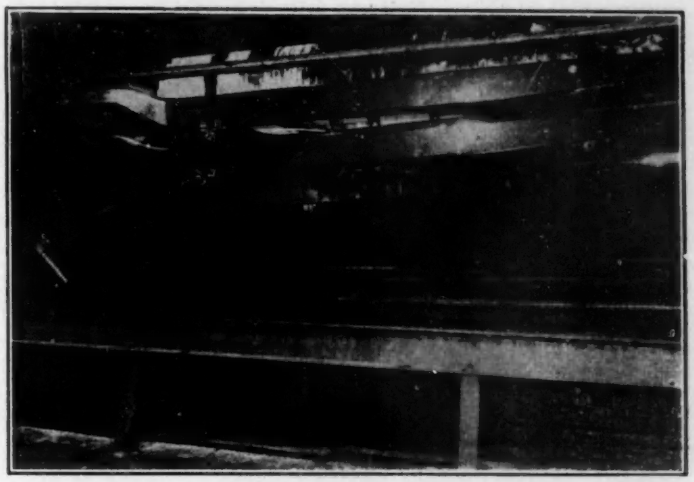

Fig. 30—Method of Hanging Frames in Pairs in the Enameling Oven
The Frames Receive Two Coats of Enamel and Are Baked in This Manner After Each Dipping

It is one of the general principles of the Studebaker Corporation to admonish employes throughout the plant that the materials they are handling are valuable, consisting largely of highly finished sheets, and they are requested to use care in handling them so that scratches, dents, slug-marks, and the like, shall be avoided, for such imperfections increase the cost of the finishing operation and sometimes produce a total loss of the part.

Incidentally, the production of each day is represented on a wall chart by the length of red chalk lines, the aggregate length of which represents the monthly quota. In this way all the employes can readily see just how many parts are needed to complete the month's output. Throughout the plant, method of operation and quality are considered to be more important than tools and quantity.

The foregoing covers the fabrication and assembling of some of our light sheet-metal parts and we will now take the chassis frame as an example of our practice in fabricating and assembling heavier stampings.

Steel for the frames is unloaded from cars at one side of the shop and from that point passes continuously through the various processes until it eventually reaches the final assembling line. There is no back-tracking. Specifications under which the steel is purchased cover both its physical and chemical properties, including drawing quality, dimensions and gage. Samples from

Fig. 31—Frames Emerging from the Enameling Oven
They Are Automatically Released from the Carrier and Slide Down This Chute To Receive Further Minor Assembling Operations

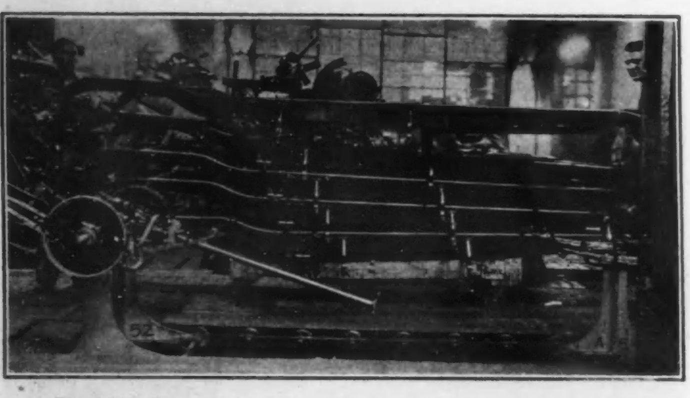

FIG. 32—FRAMES READY FOR THE FINAL ASSEMBLING LINE
As the Last Operations of Frame Assembling Are Only a Few Feet from the Final Assembling Line, Only a Small Stock of Finished Frames Are Necessary and These Are Handled on Trucks, 5 per Truck

each shipment received are taken by the inspection department and undergo thorough laboratory tests, the steel meanwhile being held in stock until it is released by the laboratory.

FABRICATION OF SIDE-RAILS

The first operation on the side-rails is to blank and pierce at the same time, the same blank being used on both sides of the frame. The second operation is the forming of the rails on the same press that is used for blanking, a view of which is shown in Fig. 23. From 6000 to 8000 rails are blanked in each set-up before forming. Scrap from the blanking operation is passed immediately from the press to the shears to be cut into usable sections, as has been shown in Fig. 1. These are used up later on gussets, cross members, and the like.

Due to the fact that we pierce before forming, it is necessary to keep a close check on all holes to ensure their proper relation to other parts on the assembling line. At this point the blanks are put into steel stock-racks, which can be piled 10 high, as is shown in Fig. 24, from which they are taken later in daily lots to subsequent operations.

The next series of operations is the assembling of the spring hanger castings, for which hot rivets and pneumatic squeezers are used, one of these machines being shown in Fig. 25.

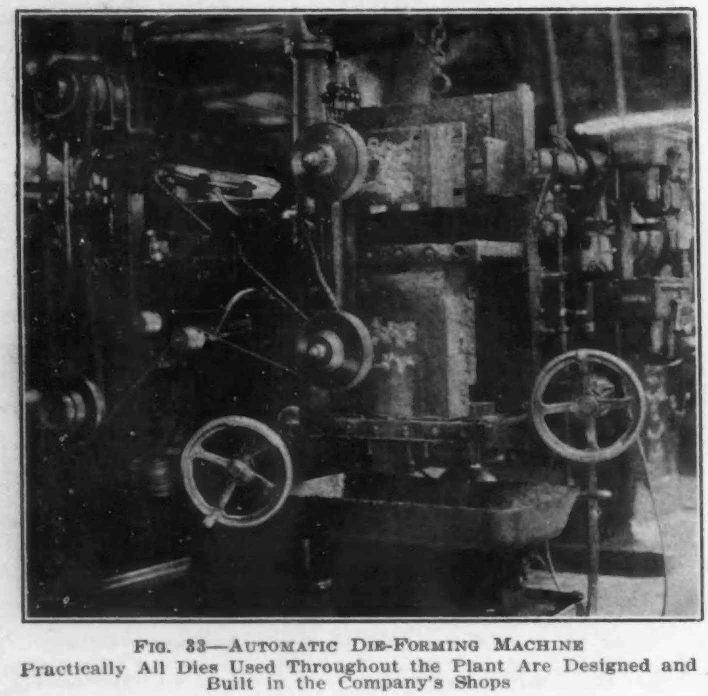

FIG. 33—AUTOMATIC DIE-FORMING MACHINE
Practically All Dies Used Throughout the Plant Are Designed and Built in the Company's Shops

ASSEMBLING OF CROSS-ASSEMBLIES

From this operation the rails pass to a pneumatic assembling fixture that assembles them with the cross members and gussets that have previously been made up into small assembling units. These sub-assemblies include the front and rear torque cross tubes, the sub-frame assembly, and the brake shaft cross member assembly. Fig. 26 depicts a pneumatic frame assembling fixture being loaded with sub-assemblies and Fig. 27 the same frame being removed from the fixture.

After the cross tubes have been squeezed into the rail, they are expanded by a tapered plug and riveted permanently into place. The frame, being now completely assembled but not riveted, is placed in a revolving cradle, which is shown in Fig. 28, that holds all the members in their correct relative positions. These cradles are on an endless conveyor.

This revolving fixture makes it possible to rivet the frame from both sides, while at the same time ensuring that the frame will have the proper dimensions after riveting. As the frame passes along the line, the riveting is performed by groups, each of which is composed of three men, a hammerman, a sticker and a bucker. Each gang is responsible for a certain number of rivets, and the entire frame is inspected afterward to make sure that no rivets have been left out or are loose.

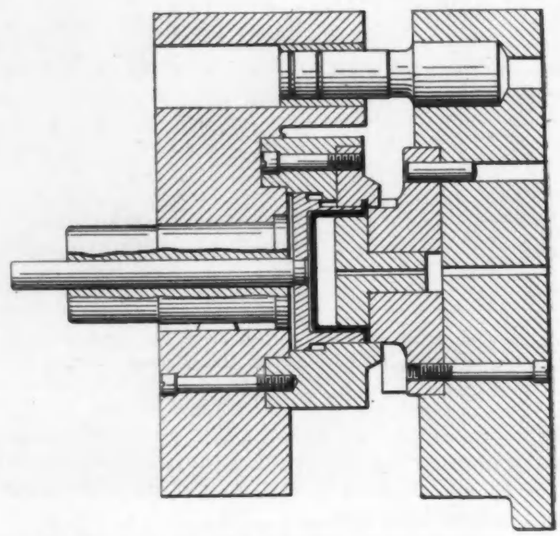

FIG. 34—TYPICAL CROSS-SECTION OF DIE
All Blanking and Trimming Dies and Almost All Forming Dies Are Equipped with Hardened and Ground Steel Liner Pins and Bushings. The Shanks Are of Steel and Are Inserted with the Shoulder at the Bottom To Prevent Their Pulling Out

It is very important that the forming and blanking dies be accurate, because if they are not, much time will be lost in adjustments while assembling, for no holes are drilled during that time.

DRILLING OF BODY BOLT AND ENGINE BOLT-HOLES

The next operation in the frame-assembling line is the drilling of the body bolt and engine bolt-holes in one jig, to ensure the correct relative position of the holes on the chassis. After these holes have been drilled as illustrated in Fig. 29, the jig is lifted from the frame by an electric hoist and is placed on the following frame. Hot rivets are used throughout and produce tight joints with no fractures in the frame around the rivet holes.

The present capacity of the frame assembling conveyor as now operated is 45 frames per hour.

When the frame has been completed it is transferred to a hot bath for cleaning prior to enameling. The conveyor that carries the frame through the bath is part of an endless system that conducts it through a continuously operating oven, in which the frame receives two coats of enamel and is baked at a temperature of 300 deg. fahr. after each dipping. During this process, the frames are hung in pairs, as shown in Fig. 30. After emerging from the enameling oven, the frames are automatically released from the carrier and slide down a chute, which is illustrated in Fig. 31, to receive minor assembling operations, such as assembling the battery connection, step hangers, steering-gear bracket, and the like. The frames are now ready for the final assembling lines, and are stacked on a truck in piles of 5, as shown in Fig. 32.

Conclusion

In conclusion, we will say that practically all our dies are designed and built in our own shops, the steel sections of all forming dies being shaped on Keller toolroom milling-machines, a view of one being given in Fig. 33.

All blanking and trimming dies and almost all forming dies are equipped with hardened and ground steel liner pins and bushings, as shown in the drawing reproduced in Fig. 34. The shanks are of steel and are inserted with the shoulder at the bottom to prevent their pulling out.

THE IGNITION OF GASES

At a recent sectional meeting of the British Association, Prof. H. B. Dixon of Manchester, before giving an account of the experiments he had been conducting for the last 3 years for the Safety in Mines Research Board, briefly reviewed the history of the gas-ignition problem. Bunsen had been under the erroneous impression that the spread of the flame was synchronous with complete combustion. Mallard and Le Chatelier observed that mixtures of hydrogen and oxygen and of methane and oxygen behaved differently; in the former case the ignition point was lowered as the oxygen percentage was increased; in the latter case the ignition point was raised. Those experiments on spark ignition were made in tubes and cylinders; in tubes the initial normal phase of combustion was followed by an irregular phase of higher velocity. The explosive wave was first invisible and, Professor Dixon found, started very slowly, the pressure wave running quicker than the flame; the sound wave was reflected by the walls and at the end, and might cross the photographic record several times. The position of the ignition point was very important; a spark right at the end of a wide tube, 100 ft. long, would not start a flame at all, as had been observed at Eskmeals. The gas surged in the tube. The part played by electrons in these phenomena was not yet clear; Professor Dixon had not been able to observe any effects due to a magnetic deflection of the electrons, but strong electric fields might stop the flame.

The photographs obtained with ignition by rapid adiabatic compression were very different from those of spark ignition. The combustion was so gradual that its beginning and the ignition point were indistinct, and hardly any cross waves were noticeable. Producing by a piston the amount of compression that would just fire a gas mixture contained in a cylinder, Professor Dixon found that further advance of the piston must be stopped as soon as ignition occurred; and Tizard had then pointed out that recoil of the piston must also be prevented. The latter was not so easily managed. Professor Dixon let the weight actuating the piston fall on a lead disc that was fixed to the outer end of the piston; this disc was stopped by a collar, the position of which was determined by preliminary experiments, and flattened out by the impact while the piston was arrested. His later horizontal toggle-joint machine was somewhat of the Ricardo type. With these machines it was again observed that with one, two or four volumes of oxygen to two volumes of hydrogen, the ignition point was lowered from 521 deg. cent. (970 deg. fahr.) to 488 and 452 deg. cent. (910 to 846 deg. fahr.) while in methane-oxygen mixtures the ignition point was raised from 406 to 430 deg. cent. (763 to 806 deg. fahr.). With methane-air mixtures the ignition point was slightly lowered as the air percentage increased from 90.5, volume for complete combustion, to 93.0; after that the ignition point rose rapidly. Ethylene behaved like hydrogen. With electrolytic gas, a rapid self-heating mixture, the clamping of the piston had a small but measurable effect; with a slow self-heating mixture, methane-air, the clamping of the piston made an important difference because the gas had time to work on the piston during the self-heating period.

The exact determination of the ignition point being difficult in these machines, experiments were also made with concentric tubes, the inflammable gas escaping as a jet from the orifice of a vertical tube within a silica tube filled with the other gas, both the gases being preheated. The whole was contained within a cylindrical furnace that was protected by a steel case. The inflammable gas could be turned on suddenly when the furnace was at the desired temperature; the gas pressure could be raised to 7.5 atmospheres and lowered to 75 mm. (2.95 in.). Below this pressure no explosion would take place in methane and oxygen mixtures; at 100 mm. (3.94 in.) methane would ignite with a distinct time lag, and the lowering of the pressure lowered the ignition point, from 631 deg. cent. (1168 deg. fahr.) at 760 mm. (29.92 in.) to 500 deg. cent. (932 deg. fahr.) at 75 mm. (29.52 in.). But the maximum ignition-point rose with most gases, notably with hydrogen, first as the pressure was increased, and then fell with a further increase of pressure. When the furnace was cooled the ignition lag increased up to 15 sec. in some cases, with ethylene-oxygen from ½ to 10 sec. Incipient combustion before visible combustion was observed in many gases, but only carbon disulphide and ether had so far proved suitable for these studies.—*Engineering* (London).

Air-Cooled Aircraft-Engine Development

By S. D. HERON[2]

THE development of air-cooled aircraft engines has been in progress by the engineering division of the Air Service for the last 5 years. Cooling had ceased to be anything but a minor problem by the middle of 1922 and since then the major aim in regard to cylinders has been to produce a construction that is mechanically durable and that does not deteriorate from warping, growth and thermal stresses when subjected to protracted service at full power. Further, it is a fundamental requirement that the construction shall be a good production design, each operation being readily open to inspection during manufacture, for, while efficiency rather than moderate first cost is the aim, high cost represents man-hours and difficult construction involves special facilities, both of which are at a premium in times of military stress. The result of the Engineering Division's efforts with regard to cylinder construction has been to produce a design that, although far from finality, yet fulfills these requirements.

The activities of the Division in multi-cylinder engine development have been centered in the engine of 400 hp. and over. Working in conjunction with the aircraft industry, two successful 400-hp. types have been produced. The first is the Curtiss R-1454 nine-cylinder radial engine that develops 400 hp. at 1650 r.p.m., with considerable reserve, and weighs 740 lb., complete, with built-in hand starter and supercharger. This engine has set a new standard in smoothness of running for large single-row radial engines, due almost entirely to the supercharged induction system. After the development tests were partly finished with a temporary type of cylinder that was extremely durable, but very crude in regard to head-resistance and valve-gear, the engine was reworked to take a later type of cylinder.

The V-type air-cooled engine, which was practically dead since 1917, was revived by the Engineering Division. The single-row radial engine was not considered suitable for power in excess of 500 hp. because excessive head-resistance and mechanical difficulties with valve operation, connecting-rods and pistons. The Division has reasons for believing that the double-row radial engine with staggered cylinders is inferior to the single-row radial, V or X-types, on account of cooling trouble with the rear row of cylinders and because of the difficulty of securing a durable and efficient type of valve-operating gear. The result of this attitude was the production of an air-cooled Liberty-12, designed by the Engineering Division and built by the Allison Engineering Co. It consists of a standard Liberty-12 whose water-cooled cylinders are replaced with air-cooled cylinders and new pistons and valve-operating gear. The cylinders are 4⅝ x 7 in. as compared with the 5 x 7-in. water-cooled cylinders. This engine develops 420 hp. at 1900 r.p.m. and has passed a 50-hr. test, developing 380 hp. at 1880 r.p.m. The net installed weight is from 200 to 230 lb. less than that of the standard water-cooled type. It will cool continuously at full throttle while stationary on the ground with the blast supplied by its propeller of normal-flight type.

The fact that it is easy to cool the air-cooled Liberty, embodying a 45-deg. included angle between cylinder banks, shows that the 1000-hp. air-cooled engine is in no sense a radical step. If an X-type with a 90-deg. angle between the banks of cylinders and 24 cylinders be adopted, it is possible to obtain 1000 hp. or more without the required power per cylinder exceeding that obtained in the Curtiss R-1454 single-row radial engine and without anticipation of cooling trouble. The design and construction of such an engine are already under way.

In the improved air-cooled cylinder construction developed by the Engineering Division, the head is a heat-treated aluminum-alloy casting screwed and shrunk onto a steel barrel having integral steel-fins machined from the solid. The valve-seat inserts are of aluminum bronze and are shrunk into the heads. A steel clamp-ring is shrunk over the lower end of the head so that the head is nipped between two steel surfaces that prevent stretching and movement of the head on the barrel and eliminate possibility of leakage there. Both inlet and exhaust valves are of glass-hard steel and operate in glass-hard tungsten-steel guide-bushings, thus preventing wear. The exhaust valves are cooled internally by a mixture of fused sodium and potassium nitrates contained in the hollow stems. The valve-gear is of the compensated constant-clearance type and is entirely enclosed and lubricated by the force-feed system. The mean effective pressure developed exceeds anything known to the Division in air-cooled cylinders. The cylinder of the radial engine is of 5⅝-in. bore by 6½-in. stroke and has a compression ratio of 5.4 to 1. When running at 1800 r.p.m. it regularly pulls 145 lb. per sq. in. brake mean effective pressure, and occasionally has done 158 lb.

The air-cooled Liberty-engine cylinder follows the same general construction except that an overhead camshaft valve-gear is used. The method of shrinking-on the head clamp-ring is of interest. It cannot be dropped on the cylinder barrel after the head is shrunk on but has to be loosely attached to the barrel while the head is shrunk. It cannot then be heated for shrinking by normal methods without heating the head and barrel. This is overcome by passing a heavy low-tension current from a butt-welding machine through the ring, which heats it to the shrinking-temperature in a few seconds.

The aluminum cylinder-head castings are produced from stripper-plate patterns upon jolt-ram molding machines and are a much simpler and an easier job than an aluminum water-cooled cylinder casting. An aluminum alloy consisting of 4 per cent of copper, 2 per cent of nickel, 1½ per cent of magnesium and 91½ per cent of aluminum with iron 0.60 per cent maximum and silicon 0.40 per cent maximum has been standardized for cylinder-head castings. This alloy has remarkable strength at high temperature and produces very sound castings that do not warp in heat-treatment. It also gives remarkably good results in pistons and piston-pin bushings.

[1] Abstract of an address at McCook Field, Dayton, Ohio, made to representatives of the American Society of Mechanical Engineers and members of the Dayton Section.

[2] S.M.S.A.E.—Aeronautical mechanical engineer, engineering division, Air Service, Dayton, Ohio.

Training Employes in Production Work

By Lillian M. Gilbreth[1]

Production Meeting Paper *Illustrated with* Charts and Photographs

ABSTRACT

SUCCESSFUL production demands the greatest amount of output with the least amount of effort. It is of prime importance in industry, and its slogan is the elimination of waste, considering always the worker, surroundings, equipment and tools and the methods or motions used. Therefore, it is necessary to give attention to training employees in production work. The paper evaluates training in terms of production and formulates the elements that have proved effective, the aims of such training being to develop a better worker in the particular job, to produce a better member of industry and to create a better member of society.

The worker always must be judged with relation to his work, and no more important psychological test exists than that of aptitude for the job. The surroundings, equipment and tools warrant intensive study, but great care must be taken to avoid duplication of work already done and to make use of the advice of experts regarding heating, ventilating, fatigue and posture. The chief emphasis must be placed on methods or motions used, and these must be carefully investigated, standardized, and taught, considering the factors of teaching under the headings *what* is to be taught and *who* is to teach it; and *when, where, how* and *why* it is to be taught.

The "*what* is to be taught" includes consideration of the problem of industry itself, of the plant and of the department in which the worker is, of the operations that he performs and the like. It involves a study of both the aptitude and the handicaps of the learner, and covers Fatigue Study, Motion Study and Skill Study. The method of attack includes the elimination of motions and fatigue, the simplification of methods, the standardization of accepted practice and the maintenance of the "one best way" that has been standardized.

Transference of skill is the primary concern of the teaching, which considers constantly the "therbligs" or elements of motions that are the units by which skill is measured. Teaching can be done by any worker, although this is seldom profitable because the worker may have no training in teaching and has seldom an incentive to teach. It can be done by the foreman, who has both time and incentive, but is seldom trained. It can be done profitably by a training department, through supplementary courses or by an expert who understands both teaching and the work to be taught.

Training should not be confined to any one period. It should start in the employment department, with the selection of the worker and making him acquainted with the work he is to do. It should continue through the training period and through constant follow-up during the entire life of the worker in the industry. Meetings, both within and without the organization, assist in the training and are a valuable stimulus. A certain amount of training can be done profitably in the laboratory or department of training, but much must be done at the workplace itself, under the actual working conditions and with the working incentives. This is so important that teachers should themselves be retrained at stated intervals under plant working-conditions to make sure that the instructions meet the actual practical needs.

Every possible vehicle of instruction should be used; the eyes, the ears, and the motor senses should be trained. Both the micromotion and cyclegraph methods appeal to many senses and build up an adequate learning process. Fatigue always must be considered in all training. Eye fatigue must especially be avoided by blindfold teaching and by using the hearing and other senses whenever possible. Great emphasis must be laid on teaching the learner to think in terms of motions and elements of motions. This is the most valuable result of the type of training here advocated, and is a specific means of evaluating training for production.

It is because of the importance of the transference of skill that teaching is such a vital element of efficient production. None but the best teaching is suited to industrial needs. Progress along this line in the last 10 years is most encouraging and, instead of tracing the effects of education in schools and colleges upon industrial education, we may expect to find marked traces of the effects of training in industry upon school practice.

The result of the teaching here advocated is a definite increase in training in industry. Illustrations of the applications of the methods outlined in various industrial fields, especially in the automotive industry, prove that output can be increased many times through efficient teaching. While these results show the needs of other factors in scientific management besides teaching, they never could have been attained without the teaching, no matter what the changes in working conditions. Further, while efficiency from the motion-study standpoint is not the only test of efficiency of teaching for production work, such teaching does make possible the evaluation of existing practice, which is the first step in progress.

PRODUCTION is the most important phase of industry, from the economic, the engineering and the educational standpoints. It is for this reason that training employes in production work is of paramount importance, whether they are engaged directly in production itself, or indirectly, by belonging to the planning, the training, the selling, or any other than the production, department. This paper evaluates training in terms of production.

Aim of Training

Fortunately, the aim of production training is not narrow; it makes the learner more efficient, no matter what his line of activity may be. Such training should have three distinct yet closely related aims: First, to develop a better worker in the particular job; second, to produce a better member of industry; and third, to create a better member of the community at work, at home and in society.

Industry is justified in demanding profits through its production, and in demanding that any training of those employed in the industry shall result ultimately in profits. Research, training, planning and all similar activities must finally submit themselves to evaluation in dollars and cents. They may demand adequate records and criteria extending over a sufficient period of time to

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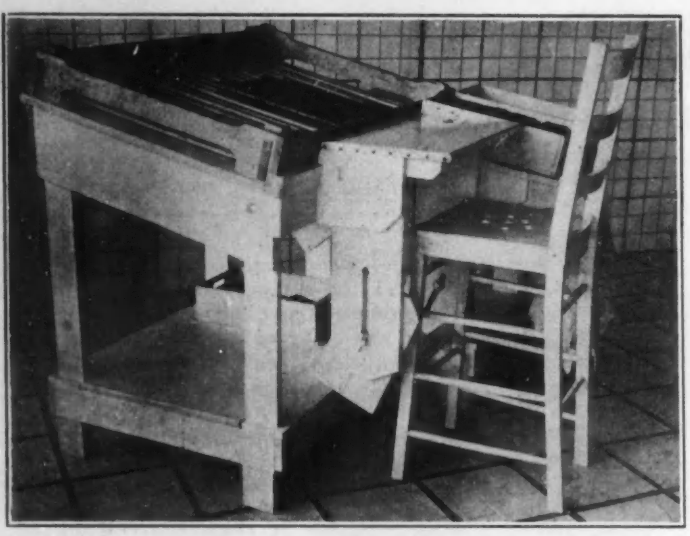

FIG. 1—AN EFFICIENT WORKPLACE
This Illustrates a Worktable Specially Designed for Work When Standing or Sitting, and Its Accompanying Special Chairs and Footrest. The Equipment Is Shown in the Cross-Sectional Laboratory Where It Is Studied for the Purpose of Doing Preliminary Teaching There

prove their value but, in return for these, they must submit to being measured by the same standard as that which measures other industrial activities and to having their results compared with the results of these other activities. It is only when these demands are understood and met that science, on its human as well as on its material side, can succeed in demonstrating its value in the industrial world. It is because this is realized that we make training the worker to be more efficient in his particular job the *first* aim of employe training. Through such training the worker must be able to measure himself and his capabilities against the requirements of the job, to understand how these requirements are best met, to formulate the method of attack upon the work itself and, finally, to turn out the greatest amount of production with the least amount of effort and consequent fatigue. This specialized training in itself will make him a better member of industry, as elaborated in a chapter on the Effect of Motion Study on the Worker[2]; but it is with the second aim in view that the training is broadened to include *likenesses* between the particular job studied and other jobs both in and out of the industry and a study of the fundamentals of skill and its transference, with emphasis on the relation of the particular job to the other jobs included in the plant, in that special line of work, in the industry of the community and in industry as a whole.

To fulfil the third aim and make the training result in a better member of the community, it is necessary to stress the underlying laws that govern the procedure taught. Something of physiology and of psychology, of economics and of engineering, enter, not in their theory but in their working practice and with definite application to the problems in hand. This last type of training, if given without connection with the second or the first types, might prove broadening and stimulating but not directly useful. It might not show an immediate and concrete effect on the pay envelope; but, properly balanced, the three together will make the worker not only a more efficient person socially but, at the same time, more flexible of body and of mind and better able not only to learn but to teach.

FACTORS OF SUCCESSFUL PRODUCTION

Successful production demands the greatest amount of output with the least amount of effort. Its slogan is "Elimination of Waste," considering always the worker, his surroundings, his equipment, and tools and the methods or motions he uses.[3] The worker must always be judged with relation to his work and his efficiency estimated in terms of his suitability to the work to which he has been assigned. No intelligence or other test is of specific value in industry until it considers the work which it is planned that the worker tested shall do, preferably considering which abilities will be a handicap as well as which will be an asset. It is a part of the training of the worker to teach him to estimate both his faults and his good points. It is he who is primarily interested in job analysis as well as in personality analysis, and his own opinions as to his qualifications for the job, its requirements, his satisfaction with it and its rewards, are of great importance. An appetite for the job, once advocated only by pioneers in management, has become universally accepted as a prime requisite of success, reference being made in this connection to an article on Scientific Management in Other Countries than the United States.[4] We may speak of incentive, motivation or interest, as we are engineers, psychologists or educators. It remains the same thing, the fundamental hold of the work on the worker.

The worker should be trained, as should the management, that work which but partly occupies his attention and abilities cannot be permanently satisfactory and that he should be taught the highest type of work that he is capable of doing, even at the expense of much effort on his own part and on that of the management, so that he may get that durable satisfaction which comes only from giving one's best continuously. Efficient surroundings, equipment and tools furnish an almost unlimited field for study. The important thing here is to utilize all sources of information available. Data on

FIG. 2—ROUTE MODEL
The Placement of Equipment and a Visualization of Efficient Routing of a Product through the Manufacturing Processes Is Shown. The Model Makes It Possible To See the Planned Improvements before They Are Carried Out

[2] See Applied Motion Study, by F. B. and L. M. Gilbreth.
[3] See Motion Study, by F. B. Gilbreth.
[4] See *Bulletin of the Taylor Society*, June, 1924, p. 132.

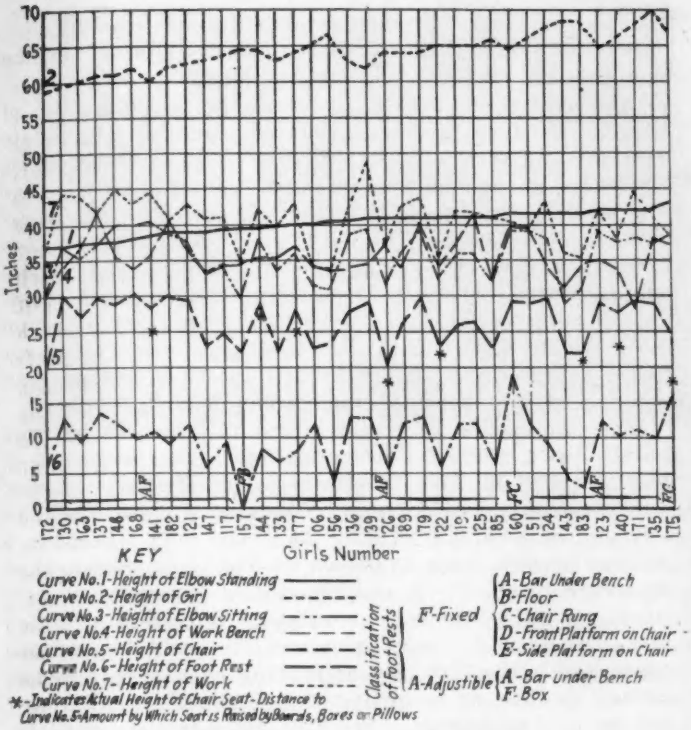

FIG. 3—FATIGUE-SURVEY CHART

In Graphical Form, It Shows the Height of a Girl When Working, and the Respective Heights of Her Elbow When She Is Standing and When She Is Sitting, As Well As the Heights of the Chair, the Footrest and the Work

ventilation and heating are at hand and immediately usable. Posture and fatigue are being investigated by experts of the American Posture League, New York City, and by those of the Committee for the Elimination of Unnecessary Fatigue of the Society of Industrial Engineers, Chicago. Rules for good health are in standard form.

Laboratory study of an efficient workplace is illustrated in Fig. 1. Any duplication of effort is not only wasteful but inexcusable. Enough work is to be done without repeating, more or less ineffectually, what already is being well done by others, and likenesses between the different types of activity in industry are so much more important than are differences that most of the material already accumulated can be used easily and effectively.

When we come to standardize work methods that embody the quickest, easiest and best directed motions, we have a field that must be investigated not only in each industry, but in each operation and process involved. Employe training must, then, expect to specialize and expand in this field.

FACTORS OF TEACHING

Perhaps no better way exists of grouping the various topics that should be taken up by teaching than to place them under the old headings: *What* should be taught, *who* is to teach it, *when* is it to be taught, *where* it is to be taught, *how* is it to be taught, and *why* is it to be so taught.

The first necessity in presenting *what* is to be taught is to visualize the problem. The teacher and the student must be able to understand and to agree upon what industry is as a whole; what the particular plant in which the work is being done stands for and is doing; the work of the department; the operations performed in it; the processes under each operation; and, finally, the cycles of motion and the elements of these cycles that constitute the work of the specific employe himself.

The aptitudes and handicaps of the worker must be considered.[5] Some understanding must be had of fatigue,

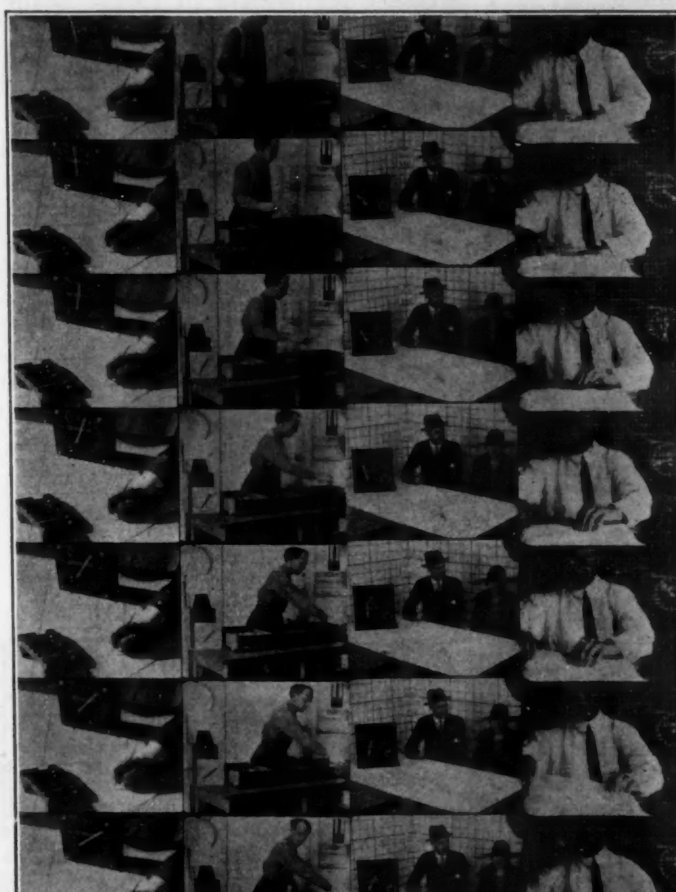

FIG. 4—MICROMOTION FILM

Such a Study Provides Accurate Records of the Work Done, the Time Occupied in Doing the Work and the Methods Used, Being Also an Effectual Teaching Device

[5] See Motion Study for the Handicapped, by F. B. and L. M. Gilbreth.

its causes, its results and the methods by which it can be eliminated or recovery provided.[6] Finally, if the work is to have the greatest amount of interest, some investigation into skill and its transference must be made. Skill study, even in its most elementary phases, adds interest. It is a necessary complement of motion study and fatigue study. Fatigue study eliminates unnecessary work; motion study makes work more efficient and easy. Skill study makes it progressively interesting.

It is perhaps scarcely necessary to enumerate visualizing devices, especially since some of these will be referred to later under *how* the teaching is done. Charts of all sorts, such as the organization, the functional and the process charts, aid visualization. Route models and pin plans put layout and paths of men, materials or product into clear form for discussion, the method being indicated in Fig. 2. Micromotion films and simo-charts, cyclegraphs and motion models visualize methods, and the "frames" cut from the films and pasted on instruction sheets or the chronocyclegraph records used as summaries of cycles of motion tell, as no descriptive wording could, exactly *what* is desired, in detail.

A second thing that is to be taught is the method of attack. To increase production, one must (*a*) eliminate motions and fatigue; (*b*) simplify existing methods, by analyzing them into elements and then adding together the best and the shortest elements to form the new work-process; (*c*) standardize, that is, crystallize the findings into such devices as simultaneous motion-cycle charts and instruction sheets; and (*d*) maintain, through standing orders, such as referred to in a previous paper on The One Best Way to Do Work[7], charge orders, the suggestion system, adequate records and programs[8], and such charts as the statistical department furnishes.

The elimination of motions and fatigue can be done partly by a survey. Even the most inexperienced of learners will be able to eliminate unnecessary activity and the consequent fatigue by making a close study, *in writing*, of what he actually does, and why. Perhaps a fatigue survey, such as shown in Fig. 3, is the simplest on which to start.[9] It can be applied anywhere, is easy to do, is non-controversial, attracts universal attention and interest and results in immediate profit to everyone concerned. The difficulty of making even such a simple survey as this, of recording things exactly as they are, not as one wishes they were or intends they shall be, and of looking the facts squarely in the face, is a highly educative process. The written survey can, of course, be supplemented by photographs and, better still, by micromotion films such as shown in Fig. 4, which record what is actually happening, a clock being connected with the record to supply the time element and also preferably, a cross-sectioned background that aids in locating any specific point to which attention is directed.

The process of simplification demands, first, records of the best existing practice; then the selecting from these records of the most efficient elements and combining these into a new "one best way" of doing the work. The records upon which the standardization is made are absolutely accurate and of permanent value, in contrast to the unsatisfactory features cited in a previous paper on An Indictment of Stop-Watch Time Study.[10] The data from these are transferred to simultaneous motion-cycle charts that show which members of the body perform the activity under consideration and how long it takes to do each element of the work. Upon these charts, also, the therbligs or 17 elements of a cycle of motions are recorded. In this way the activity is classified, as to which elements it covers and as to the relative importance of these elements with relation to one another as brought out in previous papers on Classifying the Elements of Work[11] and on the Application of Motion Study.[12] The one best way, considering the available worker, his surroundings, equipment and tools, is transferred to the instruction sheet, which becomes the manual and textbook for the learner not only as to *what* is to be done and *how* it is to be handled, but with the results required, in both time and output.

Perhaps the most important element to be emphasized in learning a new method is that of maintenance. This is provided for through the instruction card and the standing order, described in a previous paper on Maintenance of Management[13] which contains the various factors as already listed under the teaching process; namely, the *what, who, when, where, how* and *why*. The change order supplies the mechanism for change. The suggestion system supplies a vehicle for bringing desirable changes to the attention of those in authority, and

[6] See Fatigue Study, by F. B. and L. M. Gilbreth.
[7] Presented before the Society of Industrial Engineers, May, 1920.
[8] See Psychology of Management, by L. M. Gilbreth.
[9] See Fatigue Study, by F. B. and L. M. Gilbreth.
[10] See *Bulletin of the Taylor Society*, June, 1921, p. 100.
[11] See *Management and Administration*, August, 1924, p. 151.
[12] See *Management and Administration*, September, 1924, p. 295.
[13] See *Scientific American Supplement* No. 2161, June 2, 1917, p. 345.

Symbol	Name of Symbol	Name of Color	Name and Number of Pencil or Crayon
	Search	Black	Dixon's Best Black No. 331
	Find	Gray	Dixon's Best Gray No. 352½
→	Select	Light Gray	Dixon's Best Gray No. 352½ Applied Lightly
∩	Grasp	Lake Red	Dixon's Best Lake Red No. 321½
	Transport Loaded	Green	Dixon's Best Green No. 354
9	Position	Blue	Dixon's Best Blue No. 350
#	Assemble	Violet	Dixon's Best Violet No. 323
U	Use	Purple	Dixon's Best Purple No. 323½
	Dis-Assemble	Light Violet	Dixon's Best Violet No. 323 Applied Lightly
0	Inspect	Burnt Ochre	Dixon's Best Burnt Ochre No. 335½
8	Pre-Position for Next Operation	Sky Blue	Dixon's Best Sky Blue No. 320
	Release Load	Carmine Red	Dixon's Best Carmine Red No. 321
	Transport Empty	Olive Green	Dixon's Best Olive Green No. 325
	Rest for Overcoming Fatigue	Orange	Rubens "Crayola" Orange
	Unavoidable Delay	Yellow Ochre	Dixon's Best Yellow Ochre No. 324½
	Avoidable Delay	Lemon Yellow	Dixon's Best Lemon Yellow No. 353½
	Plan	Brown	Dixon's Best Brown No. 343

Fig. 5—Therbligs Chart

The Symbols of the Elements of a Cycle of Motions and a Scheme of Colors by Which They Can Be Represented on the Simultaneous Motioncycle-Chart Are Shown

FIG. 6—WORKPLACE STUDY
A Study of the Work at the Workplace, with the Existing Workers and under Existing Conditions in Regard To Equipment, Tools, Surroundings, and Methods of Work, Has an Important Bearing on the Conclusions Derived

adequate records furnish not only bases for efficient judgment on the value of what is being done, but satisfactory data for making programs and predicting trends of development. No one is involved in production who should not be given an opportunity to know not only how the methods by which he works are derived, but how they are taught, installed and maintained, and what the results are, not only as they affect him, but as they affect the organization.

A third thing that should be taught is the importance of the transference of skill. The worker must be trained to *think* in terms of the decisions and motions that lie at the base of acquiring and increasing skill as outlined in a previous paper on Graphical Control of the Excep-

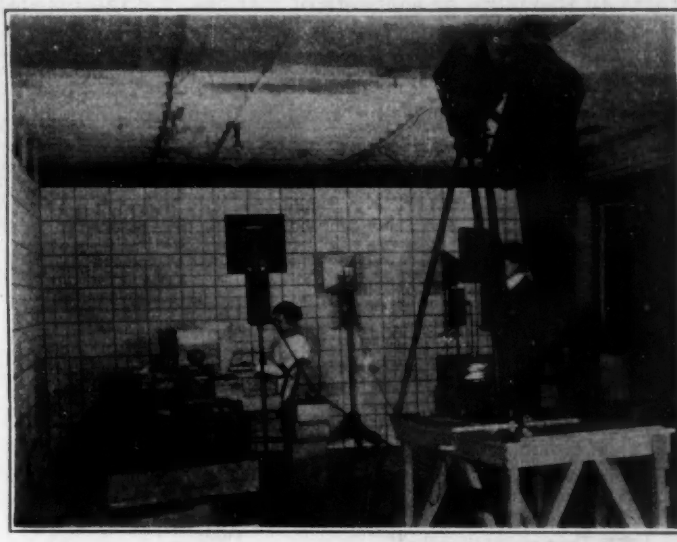

FIG. 7—LABORATORY STUDY
In Addition To Study at the Workplace, the Work Should Be Studied in the Plant Laboratory To Determine the Best Worker, Equipment, Tools, and Work Methods Available

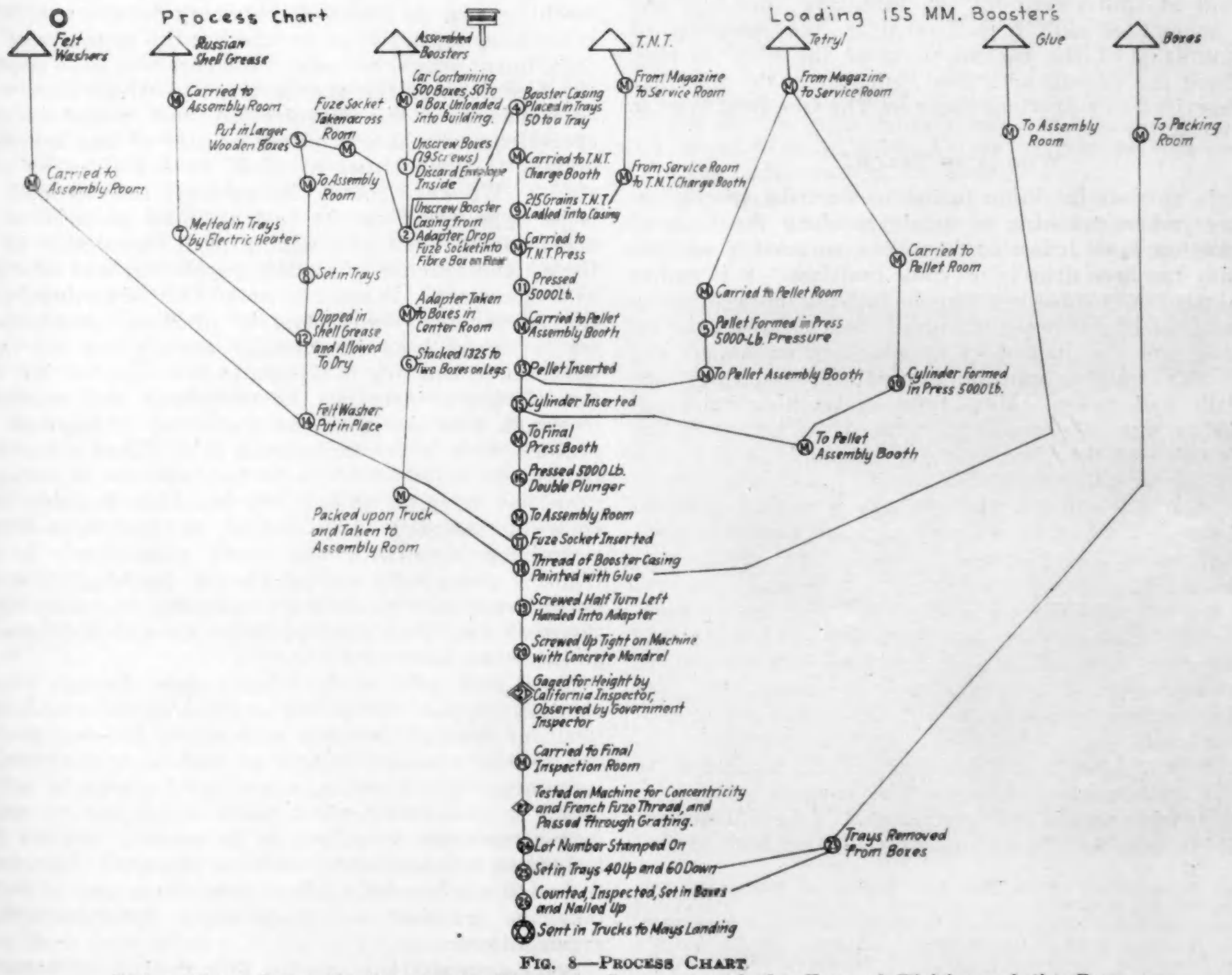

FIG. 8—PROCESS CHART
Such a Chart Shows the Steps in the Work, the Sequence, and the Type of Divisions of the Process

tion Principle for Executives.[14] In former days it was thought sufficient to think in methods, in very general terms, to aim at increasing efficiency and turning out more production, at becoming a champion or expert. Then it became necessary to think in motions, to discover the *why* of efficiency and success. Now we are coming to think in therbligs, or elements of motions, for the reason that the transference of skill depends upon likeness if not identity between the thing already known and the thing to be learned. The recent developments in motion study consist of analyzing motions into therbligs and comparing these therbligs, to establish underlying laws of efficiency in their performance. To illustrate, they are listed below without attempting to add any background or description, and are indicated in Fig. 5.

(1) Search
(2) Find
(3) Select
(4) Grasp
(5) Transport loaded
(6) Position
(7) Assemble
(8) Use
(9) Dismantle
(10) Inspect
(11) Pre-position for the next operation
(12) Release load
(13) Transport empty
(14) Rest for overcoming fatigue
(15) Other periods of unavoidable delay
(16) Avoidable delay
(17) Plan

Skill is transferred by the foregoing therbligs and the amount of skill is estimated by the relativity of simultaneity of the various parts of the body as they perform the various activities indicated in the therbligs as described in a previous paper on The One Best Way to Do Work.[15]

WHO IS TO TEACH?

It is not our intention to list or describe specific instances where teaching of employes along the lines of production here indicated has been successful, as this already has been done in previous treatises.[16] It is rather the intention to describe the underlying laws that determine success in such teaching. In this way existing methods can be judged, their efficiency estimated and plans for training can be evaluated before they are actually undertaken. Many types of teaching have succeeded because of personality, rather than because of the basic value of the plan itself. Teaching is both an art and a science. The successful teacher must have personality plus. We can indicate here only some fundamentals of the science which have been evaluated from the engineering, the psychological and the educational standpoints.

The teaching may profitably come from many sources. The teacher may be an efficient worker, who demonstrates his work methods to the learner. This method is specially effective because of the kinship between pupil and teacher, and because the learner can see the value of the methods taught in the records of successful production of the teacher himself. On the other hand the worker has seldom been trained as a teacher, and has no idea of the fundamental laws of the learning process.

The teacher may be the foreman and, if so, will succeed best if he has been taught not only the one best method but how it should be transferred and if he is made to share, in some very definite and direct way, in the success of the worker or learner. The training of the foreman will be considered here only insofar as he is a typical employe. The foreman is equipped to be a teacher in that he is in close contact with the work, is acquainted with various methods of doing it, is not required to take time from his own work to do the teaching, and is traditionally supposed to be responsible for the work. He can be really successful only if he has been trained in teaching, if he has a knowledge of the one best way and why it is the one best way and if he is convinced of the necessity of the one best way being taught. He must be in sympathy with the work and the worker, and must have a real liking for teaching. The foreman is a "key" person in industry—in production, in selling and in all other lines—and the importance of adequate training for the foreman type can scarcely be overestimated.

A certain amount of training can profitably be done by the inspector, who, at least in scientifically managed plants, always stays with the worker while he makes the first piece of a new lot, notes both successes and failures and supplies the necessary instruction. Quantity inspection, but especially quality inspection, offers excellent opportunities for finding those who need instruction and, if the instructor is able and glad to give the instruction at the time the inspection is made, it will prove not only effective but a distinct asset to the fostering of cooperation.

Today, in many organizations, the greater part of the teaching is in the hands of a training department. There is constant argument as to whether the members of this department should be trained teachers who have acquired the technique of the special plant in which they work, or members of the organization, well versed in plant operations, who have acquired greater or less knowledge of how to teach either at school or college or by other study. We have found the greatest success with the latter type, selecting the best available material of the organization itself and adding such instruction in the theory and practice of modern psychology and education as is necessary. It must be noted that educational practice advances as does industrial practice. A successful teacher must keep in constant contact not only with advances in teaching in schools and in industry, but with the literature, including the periodicals and reports of meetings, and also with the increasing widespread laboratory work in the educational field. Even a doctor of philosophy by education, who has been out of college a year, not to speak of one who has been teaching some time in industry, may return to find himself unacquainted even with the newer vocabulary. If the training department undertakes the teaching, it should furnish not only preliminary training, but training at the workplace itself, and in follow-up and maintenance, as these are necessary.

Much successful work is being done through supplementary courses. These can be given in the organization itself, or carefully selected members of the organization can be sent outside for expert instruction on theory or technique. For example, a 4-months' course in motion study is now being given twice each year to enable young engineers or others in industry to acquire this technique, thus preparing them for return to their plants to install motion-study laboratories there and to undertake the training in motion study throughout their organizations.

Some organizations prefer this method of securing

[14] See *Transactions of the American Society of Mechanical Engineers*, vol. 38, p. 1213.

[15] Presented before the Society of Industrial Engineers, May, 1920.

[16] See Fatigue Study; Motion Study; Applied Motion Study; Motion Study for the Handicapped; and Advanced Motion Study, by F. B. and L. M. Gilbreth.

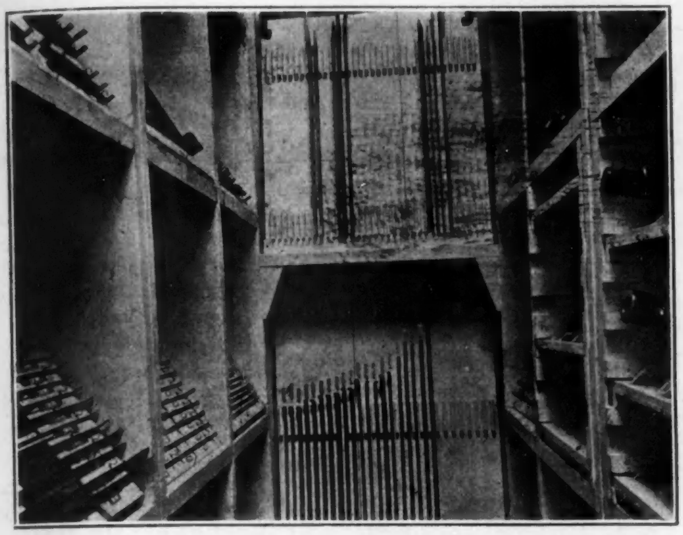

FIG. 6—ONE-MOTION TOOLROOM
It Is Painted White To Eliminate Eye Fatigue When Looking for Tools, Which Are Inspected and Sharpened before Being Put Away and Are Placed So That They Can Be Taken Out with One Motion. Such a Toolroom Does Much Toward Teaching the Effectiveness of Motion Study and Fatigue Study To an Entire Organization

expert information. Others prefer to have an expert join the organization for some time, until the organization can acquire what he has to contribute and can make its use a permanent part of the organization practice. If this method is used, adequate provision should be made for necessary teaching, both during and after the time that the expert is there.

WHEN THE TEACHING IS TO BE DONE

In an organization, the work of teaching should not be confined too strictly to any one time. A certain amount can be done profitably when the new employe is being hired. He should learn at that time much more about the organization, its work and especially concerning the opportunities in it for him than is usually the case. Attention should be paid to the correlation between the amount of such learning and the amount of labor turnover in the organization.

Up to this time, very few adequate records have been kept on the cost of training an employe until he becomes really efficient. The general policy seems to be: "Oh, we have a training department anyhow, so it might as well be busy" and, often, no attempt is made to keep account of how many members of the organization teach, how much time is spent at it and what the cost of this time is. This is true also of organizations that have no training department, or even no organized or directed training of any kind. Every minute of teaching done by anyone costs money and affects production.

It is often customary, where organized training is done, to do the greater amount during a distinct training period. A close cooperation between the employment and the training department can do such preliminary training as acquaints the applicant thoroughly not only with what has to be done in the various positions but with the methods used, in order that he shall not be shocked, startled or surprised by what is given to him during the training or the working period. A "resistance" is best discovered as soon as possible. On the other hand, those in the training department might profitably learn more of the requirements of the work and the aptitudes of an efficient worker at the work, in order that those who will not be ultimately successful can be dropped before a greater investment in their training is made. Inattention, inaccuracy and incapacity are demonstrated during the training period, and what better psychological test could one ask?

The proper organizing and operating of a training department is rapidly becoming standard practice, and this is one of the greatest advances in employe training to be recorded. No training is adequate that does not accompany the learner from the training period or classroom work into the workplace itself. Laboratory conditions can never parallel working conditions, and the place of the teacher is with the learner at the workbench until the good habits of the training department have become firmly established in the workplace itself. Figs. 6 and 7 are illustrative of the workplace and the laboratory methods of study.

Supplementary teaching may well take place in either the classroom or laboratory or at the workplace. If the teaching must cover an extended period of time and a distinct change in method, it can best take place away from the distraction of the working conditions. But here, as in the preliminary teaching, the teacher must finally accompany the learner back to the workplace to make sure that the new habits are firmly established. Habit interference will be even stronger with an older, experienced learner than with one who is younger or less experienced at the work and, until the teacher has actual proof that such interference does not take place, he cannot feel safe in considering the learning process complete. The newer method, also, must be completely "sold" to the learner. He must have absolute confidence not only in the method but in his ability to use it, and he must see with his own eyes the increase in production or feel the decrease in effort and fatigue. He must actually *make more* himself before he can be considered completely taught. He must be able to do the thing, must actually do the thing continuously and successfully, and must want to do it before he has actually learned to do it, in the right sense of the term.

If any type of work has become so thoroughly standardized that no teaching seems to be necessary, the function of the teacher has not ceased. He must follow-

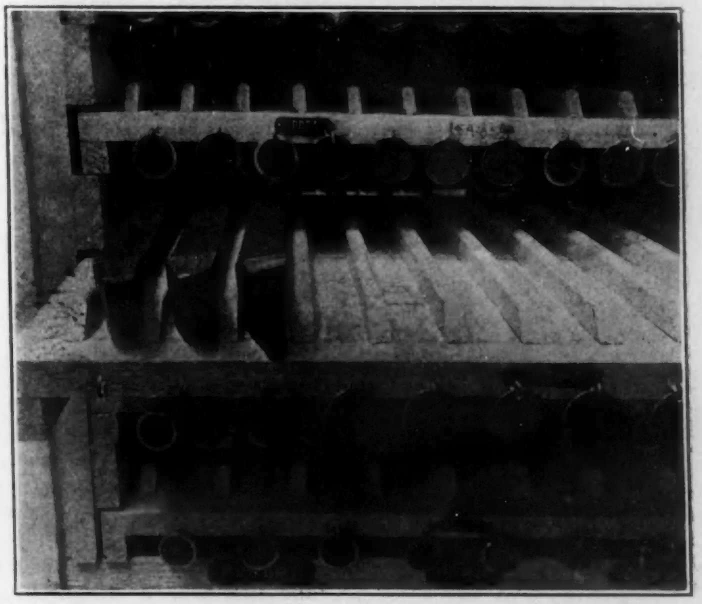

FIG. 10—TOOL STORAGE
Illustrating the Method of Storing Lathe and Planer Tools in the Toolroom on Sliding Racks So That the Cutting Edges Are in Front To Facilitate Quick Inspection. The Former Box Type of Tool Storage Required a Greater Amount of Space and Was Less Accessible

up the instruction at set periods to make sure that the methods taught are maintained. He must note every deviation from the teaching. If a similar deviation is found among many workers, and is thought by them and by the supervising force to be of value, this should be introduced to the method of teaching, after the usual measurement and standardization, and credit should be given where due. If the deviation is found to be a lapse, it should be corrected immediately and provided against in the training by special emphasis at the point where the deviation occurs.

Perhaps the greatest failure in present-day teaching in industry is the lack of follow-up. Any organization that has a training department can make a periodic survey profitably, comparing the methods as taught, the methods actually in use and the methods as approved by the workers and supervisors. It will be the exceptional industry where no discrepancies occur. The training department should never sever its connection with any employe. It can profitably point out lines of promotion and prove aptitudes by the learning records. Even where a worker remains permanently at one type of work, he may profitably receive new training occasionally, to point out good and bad points of his technique, and to show added elements of interest.

Besides such training as he receives in classes, every employe can profitably receive other supplementary teaching through meetings of different kinds, sometimes of workers engaged in similar work, sometimes of workers and foremen, sometimes of workers who are doing similar work in other shops or industries and often at technical meetings where efficient production-methods are discussed. If more workers attended such meetings and participated in the discussions, an enormous amount of new worthwhile material would find its way not only into the information of such workers, but into the proceedings of the technical societies themselves. So often, those who talk about it attend, while those who do it and even those who direct it stay at home.

Where the Teaching Is To Be Done

We have mentioned that some teaching can profitably take place in the laboratory or department of training, and that some must be done at the workplace itself. Bringing the employe into the laboratory or training department at certain times possesses distinct advantages. Nothing will convince him so thoroughly of the value of the methods that are being taught as seeing the research data upon which they are based. If he can once actually see how the standard method is derived, he will look upon all standardized methods differently, always. He may never have been the subject of a micromotion study, for example, but that is no reason why he cannot see the complete equipment for doing such work, have the methods used demonstrated, and see the resulting film and other data. He must be made to feel that he is actually a part of this work. The one best way is his and his co-workers; it is the combining of the best they can do, and never would have been available but for their cooperation. It will surprise anyone who has not had experience in this work to see how the process chart, the micromotion film, the simo-chart and the illustrated instruction card are followed easily and with the most intense interest by a worker who knows the work process intimately, even though he has no knowledge of the technique of making and using the records.

The laboratory or classroom can control variables and make accurate records, but it must never be forgotten that the actual variables of the work in the workplace are lacking, as well as the work incentive. The teacher can get information only by actually doing the work himself, in the workplace, under the working conditions and with the working incentive; that is, as a working member of the working force.

It is perhaps not inappropriate to mention here the training of teachers, as it is perhaps the greatest and most pressing need at present in the training of employes in industry. All teachers not only should go through a period of actually being workers, but they should return periodically to the status of workers and a first-hand realization of the working conditions existing at the time, and of what the teaching can be expected to do. By this means also they will become acquainted with one of the greatest needs in teaching; that is, provision for change and improvement in methods. Working conditions and equipment constantly become better and, often, so does the type of worker assigned to the work. All of these furnish a demand for a reconstructed and better method. The one best way is only the one best way while the worker, surroundings, equipment, and tools remain the same. It should be the function of the teacher to note the improvements in the various factors of the work and to see that the method is improved to meet the changing conditions and is taught and maintained in its most recent form.

How the Teaching Should Be Done

One universal rule covers this; namely, that teaching should be done by all possible known means. First, perhaps, and most important, through the eye, by manuals or textbooks or any other type of instruction, these to be supplemented by the visualizing devices that already have been mentioned, especially by process charts such as that reproduced in Fig. 8, micromotion films, cyclegraphs and anything else that will enable the learner to *see with his eyes* what he is expected to do. Second, through the ears, by lectures and informal talks, by the regular teachers and by successful workers. Third, by an appeal to the motor sense, by the use of motion models that enable the worker actually to follow with his hands the path of the motion that is recommended as the one best way.[17] Nothing is more important than actually *doing* the thing taught, to understand its difficulties and the methods that overcome them.

Demonstrations, when they are possible, should never be neglected. One may teach at length the possibility of getting certain results and may explain in detail the method of attaining them, but nothing is so convincing as a demonstration of success through using the prescribed methods.

It always should be impressed upon the learner that the eyes fatigue most easily and should be spared as much as possible. If every operation in industry could be studied with the idea of relieving the eyes, if training could be done blindfold until all those parts of the operation that could be done without using the eyes were done sufficiently, if the eyes were spared for everything but inspection, an enormous increase in efficiency of production methods would result. Blindfold teaching should be tried long and carefully before it is criticized or condemned.

A general survey of the availability of the different senses for inspection work should be made. In a certain operation in folding handkerchiefs an extra motion was

[17] See Applied Motion Study, by F. B. and L. M. Gilbreth.

detected by the ears, which the eyes could not detect because of the speed with which the work was done. Every driver of an automobile knows the efficacy of hearing as an aid to inspection. The senses of touch, taste and smell are all available and have been proved useful.

If it is an underlying aim of all teaching, as it should be, to arouse interest in motion study and in thinking in terms of motions or therbligs, object lessons should never be neglected. A one-motion pencil-rack, a one-motion rack for colored inks, these will serve to stimulate interest. Letter filing done according to the principles of motion study often has been a starting point for the entire organization. As indicated in Figs. 9 and 10, the toolroom is perhaps the best possible illustration of an efficient object lesson in motion study. A toolroom painted white, mnemonically classified, with tools put in perfect condition and arranged so that they can be removed with one motion, furnishes an object lesson that is non-controversial, demands the attention of many members of the organization, is useful to many and arouses cooperation. Assembly packets such as are illustrated in Figs. 11 and 12, cross-sectioned desks and workplaces, even such small and unimportant examples as a calendar with the dates crossed off in red pencil up to the date in use, rubber stamps with one side cut flat so that the thumb may position them for use without the need of inspection by the eyes, and efficient checking by the vertical-line method have served to arouse an interest and appreciation of motion study that no amount of exposition could attain.

The Why of Such Teaching

We have already mentioned the importance of the transference of skill. Education lies at the base of industrial progress. Without education, progress seldom can be permanent and never can be cumulative. The reason must go with the rule. Theory must underlie successful teaching. Psychology, physiology, psychiatry, economics, engineering, and education are all essential. This may seem at first glance a broad statement, yet anyone who has tried to answer questions of a worker as to why methods have been changed will know that all of his knowledge and sources of information in these fields may prove inadequate.

Education in its best and finest sense consists of two things, research and transfer, and neither of these can be neglected in the industrial field. In former days, it was thought that the postgraduate student demanded the finest type of teaching. The younger students in the colleges were given to the less experienced, less thoroughly equipped instructors, and the same thing was true all the way down the line in our colleges and schools. Today it is realized that the most adequately trained teachers are needed in the kindergarten or even in the pre-school period and that, as the learner becomes more experienced and more adept at understanding and controlling his own learning process, he can get along with less careful supervision and get benefits from less adequately trained minds. Education in industry, in any scientific way, is a new thing. The problems of teaching in industry are even more complicated than are the problems in the colleges and schools. The call is for the best knowledge of transfer, for the most complete research in this field.

Consider the variety of the learner. Consider the variety of the work to be learned. Learners stream into industry from almost every grade of our schools and colleges. We have in industry those who have learned little, those who have learned much, those who are learning constantly, and those who have stopped learning. We have eye people and ear people and motor people, people of fixed habits and people whose habits have never become established so as to be an asset. The variety of learners is infinite, as is the variety of things to be learned, and a learning process having fixed underlying laws must be applied to each individual need.

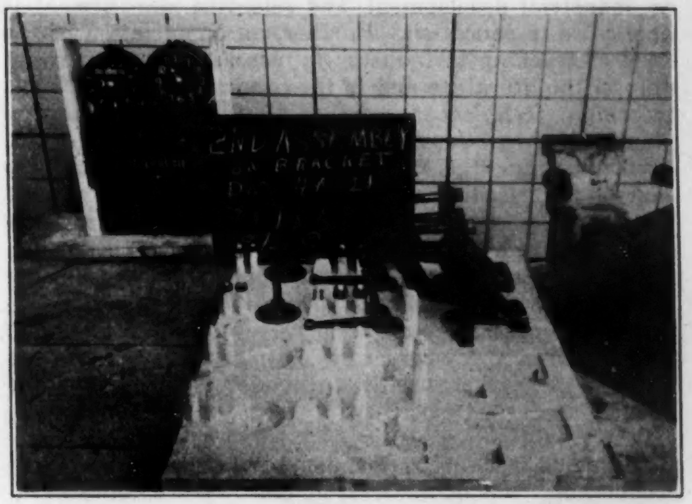

Fig. 11—Use of Packets To Speed Assemblage
The Packet for Assembling the Second Group of a Shaft Bracket Is Shown. This Group Consists of Nine Parts and the Packet Holds Parts for Four Groups. Near the Vise Shown Is a Holder for Raising the Tools So That They Will Be Close to Where They Are To Be Used, the Tools Used Being a Hammer, a Screw Driver and a Double-End S Wrench. The First Group Comprised the Bolts Seen Driven into the Bracket

Results

All of the foregoing statements sound very complicated and perhaps rather hopeless, yet the greatest strides in education today are undoubtedly taking place in the industrial field. In the past, we have listed the contributions of education to industry. In the future, we shall be listing the contributions of industry to education. New development in motion study, fatigue study and skill study, and new interest in the applications of psychology and psychiatry have come largely in the industrial field. Scientific management itself is

Fig. 12—Universal-Joint Short-Shaft Assemblage-Packet
This Group Consists of 15 Parts and the Packet Holds Enough Parts for Four Groups. The First Piece, Yoke-Shaped, Is Held in the Vise While the Other Parts Are Assembled With It in the Sequence Specified on the Packet. A Hammer, a Screw Driver, a Smoothing File and an S Wrench Are the Tools Required

an industrial development, and scientific management is applicable to education. Further, an appreciation of the need of teaching in industry is increasingly evident, not only in the literature and in the programs of the various meetings, technical and other, but in the industrial plants of the Country. Training departments are supplementing the work of planning departments; courses for executives, for foremen and for workers are increasing in number and in extent. A recent investigation made by one of the technical societies for a member abroad interested in foreman training resulted in a surprising amount of information. It seems important at present to make a survey of all that exists, to evaluate it, to discard what is unessential or of little use, and to make sure that the development is along lines of maximum efficiency.

Where efficient research and transfer work is done, the value of teaching can demonstrate itself in increased production. We quote from a paper presented several years ago,[18] because the examples cited are largely from the automotive industry.

> We have recently enabled one of our clients to reduce the time for certain operations, together with assembling large carbureters, from 450 to 45 min., thus doing the work in one-tenth of the previous time.
>
> On small carbureters, we reduced the time from 420 to 60 min., reducing the time to one-seventh.
>
> On certain operations and assembling of pumps, we reduced the time from 360 to 30 min., or to one-twelfth of the time.
>
> In a large and well-equipped motion-study laboratory, our demonstrators averaged victories of five to one; that is, we enabled the employes of our client to do the various operations in, on an average, one-fifth of the previous time required.
>
> In textile work, we have enabled the workers to produce 60 per cent more output and, after changing machines as a result of motion study, to produce from 40 to 300 per cent more work, with less fatigue. In another instance, we increased output 109 per cent.
>
> In three large factories, we have cut the cost of interdepartmental transportation one-half.
>
> In three large factories we have saved our entire fee by improving methods of handling the product during the process of manufacture by the installation of the packet system, and the nesting totebox method of handling material.
>
> In two large organizations, we have saved our fee through the salvage department alone.
>
> In five large organizations, we have saved our fee as a result of changes made from visualizing facts presented graphically.

It is true that the teaching in the various plants referred to was accompanied by such changes in surroundings, equipment, tools, and standard work-methods, as made it posssible to get the results desired; but these results never could have been attained, no matter what the changes in work conditions, without the research and transfer. It is true also that efficiency from the motion-study standpoint is not the only test of efficiency of teaching for production work; but such teaching does present measurable results that can be compared with those of other types of teaching and make possible the evaluation of existing products, which is the first step in progress.

[18] Presented before the Society of Industrial Engineers, May, 1920.

WORLD TRADE IN GASOLINE

According to a study prepared by O. P. Hopkins, of the Minerals Division of the Department of Commerce, world consumption of gasoline has increased remarkably in the last few years. American production has grown from less than 1,500,000,000 gal. in 1914 to over 8,950,000,000 gal. in 1924, an increase of 500 per cent; while our exports of gasoline have risen in the same period to nearly six times the volume of the 1914 shipments, from 217,570,941 gal. in 1914 to a record figure of 1,219,474,374 gal. in 1924. With the rapid development of the use of motor cars and of internal-combustion engines for other purposes, the trade in gasoline, both in this country and abroad, may be expected to continue to expand.

The value of American gasoline exports in 1924 amounted to more than $160,000,000, constituting an important item in our total merchandise exports for that year. Production of gasoline abroad, while not comparable with the output in the United States, has shown a rapid growth. An interesting fact is that continental United States uses approximately 79 per cent of the total world gasoline consumption, which figure corresponds very closely to the American percentage of the total world motor-vehicle registration. Another significant fact, which shows the relative importance of the United States in the gasoline industry, is that the next largest consumer of gasoline, the United Kingdom, requires annually a quantity of gasoline equal to only about 7 per cent of the American demand; while the total annual consumption in China, for example, is equivalent to about 8 hr. supply in the United States.

Outside of the United States, the countries that manufacture gasoline from locally produced crude petroleum in sufficient quantities to supply all or a large part of the domestic demand and leave a surplus for export are Mexico, Peru and Trinidad in the Western Hemisphere; Russia, Poland and Rumania in Europe; and India, Persia, the Dutch East Indies and British Borneo or Sarawak in Asia. Venezuelan oil is refined to an increasing extent in that country, but a larger proportion is exported as crude oil, chiefly to Curacao in the Dutch West Indies for refining, and the refined products are exported from that point. Columbia produces from domestic crude sufficient gasoline for practically all the country's requirements, but as yet, at least, has not developed an export trade in this product. In portions of some of these countries, as northern Persia and the west coasts of Colombia and Mexico and the northern border of Mexico, gasoline is still imported because of inadequate transportation facilities within the country or more convenient transportation from abroad, although the domestic output would under ordinary conditions render such imports unnnecessary.

Countries that produce gasoline from domestic crude oil in sufficient quantities to supply a part of the local requirements, but without a supply available for export to any extent include Ecuador, Argentina and Japan, and to a lesser degree—in proportion to consumption—France, Italy, Canada and Czechoslovakia. A domestic refining industry operating largely or entirely on imported crude oil, and supplying gasoline to the domestic market, has been established in England, Canada, Austria, Hungary and Curacao.—*Economic World.*

Applicants *for* Membership

The applications for membership received between Aug. 15 and Sept. 15, 1925, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, CARL A., sales engineer, Hercules Motors Corporation, *Canton, Ohio.*

ANDRAKE, ANDREW A., designer, Glenn L. Martin Co., *Cleveland.*

BEANS, CHARLES D., purchasing agent, Beans Spring Co., *Massillon, Ohio.*

BLAKEY, DONALD GREY, consulting engineer, *Leeds, England.*

BOYER, ROBERT, detailer, Chrysler Corporation, *Highland Park, Detroit.*

BRAND, HUGO, chief engineer, Ambi-Werke, *Berlin-Johannisthal, Germany.*

BROOKS, O. J., president, Brooks Steam Motors, Ltd., *Stratford, Ont., Canada.*

BROWNE, DONALD H., engineer, New Departure Mfg. Co., *Bristol, Conn.*

BROWNE, ROYAL S., instructor in automobile mechanics, Lake View High School, *Chicago.*

COLLINS, W. D., chief engineer, H. C. S. Cab Mfg. Co., *Indianapolis.*

CROWLEY, J. W., JR., aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

DANIELSON, ARCHIBALD G., assistant chief engineer, Diamond T Motor Car Co., *Chicago.*

D'ARCAMBAL, A. H., metallurgist and sales engineer, Pratt & Whitney Co., *Hartford, Conn.*

DAVEY, CLARENCE G., chief draftsman, A. C. Spark Plug Co., *Flint, Mich.*

EDMONSTON, RALPH T., superintendent, Tidewater Lines, Inc., *City of Washington.*

EMERSON, RENNARD BARNETT, manager, commercial vehicle department, Fiat (England) Ltd., *London W. 1., England.*

ESKIL, WILLIAM A., sales engineer, Electric Power Equipment Corporation, *New York City.*

FORCE, JOHN L., engineer, manufacturers' service division, Vacuum Oil Co., *St. Louis.*

GASKILL, FERRIS D., production superintendent, Yellow Cab Mfg. Co., *Chicago.*

GRUPELL, GEORGE H., material control supervisor, Yellow Truck & Coach Mfg. Co., *Chicago.*

GRUSE, WILLIAM ARTHUR, director of petroleum investigations, Mellon Institute, *Pittsburgh.*

HARROP, THOMAS NEWTON, senior assistant in production department, Morris Motors, Ltd., *Cowley, near Oxford, England.*

HARSTED, HARRY H., plant engineer, Yellow Cab Mfg. Co., *Chicago.*

HOPE, ELLIS, motor truck draftsman, National Steel Car Corporation, Ltd., *Hamilton, Ont., Canada.*

HOWGRAVE, A. A., manager, G. McKenzie & Co., *Mandalay, Upper Burma, India.*

HUNTINGTON, E. E., electrical engineer, Willys-Overland Co., *Toledo.*

JAYES, HERBERT, designer of machinery, Crescent Washing Machine Co., *New Rochelle, N. Y.*

KAISER, HERMAN, draftsman, Chrysler Corporation, *Highland Park, Detroit.*

KLEIN, ARTHUR HAYS, service superintendent, Greer-Robbins Co., *Los Angeles.*

KLEIN, EDWARD R., designer, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

KOPPIN, FRED W., draftsman, Chrysler Corporation, *Highland Park, Detroit.*

KUHN, LORENZ A., principal, Knights of Columbus Trade School, *New York City.*

KYLE, GEORGE LANE, electrical engineer, U. S. Light & Heat Corporation, *Niagara Falls, N. Y.*

LEA, HARRY S., labor administrator, Yellow Cab Mfg. Co., *Chicago.*

LINDBERG, W. N., manager of parts and service, Durant Motor Co. of New Jersey, *Elizabeth, N. J.*

LINDEMANN, HANS WOLFGANG, engineer, Delling Motors Co., *West Collingswood, N. J.*

LOEB, LUDWIG, director, Ambi-Werke, *Berlin-Johannisthal, Germany.*

LYONS, JOSEPH H., manager, City Transportation Co., *Dash Point, Wash.*

MACDILL, MAJOR LESLIE, chief engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

MAKITA, TETSUJI, chief engineer, Hakuyosha-Seisakushio, *Tokyo, Japan.*

MAXWELL, C. H., assistant production supervisor, Yellow Cab Mfg. Co., *Chicago.*

MAYNARD, JOSEPH S., assistant general sales manager, Richardson Co., *New York City.*

MERGEL, EDWARD C., designer, Milwaukee division, Nash Motors Co., *Milwaukee.*

MONFORT, GEORGE J., chief draftsman, Chrysler Corporation, *Highland Park, Detroit.*

MONSCHEUER, ERICH, director, Ambi-Werke, *Berlin-Johannisthal, Germany.*

MOSER, H. C., assistant general manager, Chicago Motor Coach Co., *Chicago.*

MULLER, OTTO G., draftsman, International Motor Co., *Long Island City, N. Y.*

NELSON, F. R., chief draftsman, Cotta Transmission Corporation, *Rockford, Ill.*

O'CONNOR, FRANCIS ED., Long Island sales manager, Farmer & Ochs Co., *New York City.*

PEARSON, FRANK C., research engineer, General Motors Research Corporation, *Detroit.*

PIROOMOFF, GEORGE S., transportation engineer, White Motor Co., *Cleveland.*

RIKER, M. J., service representative, Chrysler Sales Corporation, *Detroit.*

RISLEY, DALTON, JR., general manager, Craveroiler Co. of America, *Philadelphia.*

SABOURIN, WILFRID J., general manager and treasurer, York Motor Corporation, *New Haven, Conn.*

SHIPWAY, GEORGE E., president, Salt's Textile Mfg. Co., *Bridgeport, Conn.*

SMITH, JAMES W., superintendent, Standard plant, Torrington Co., *Torrington, Conn.*

SPRACKLING, GEORGE A., mechanical instructor, Chevrolet Motor Co. of Wisconsin, *Janesville, Wis.*

SPRADBROW, NORMAN H. G., production manager, Harmer-Knowles Truck Corporation, *Toronto, Ont., Canada.*

STERLING, LEROY P., assistant mechanical engineer in laboratory, Gulf Refining Co., *Port Arthur, Tex.*

TIMMONS, P. YATES, International Harvester Co., of America, *Chicago.*

TULSIDAS, VALLABHDAS, *Bombay, India.*

WILLIAMS, H. G., general superintendent, Pennsylvania-Ohio Coach Lines, *Youngstown, Ohio.*

WOOD, CLARK V., JR., superintendent of motorbus division, United Electric Railways Co., *Providence, R. I.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Aug. 10 and Sept. 10, 1925. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALBINSON, H. H. (M) designer, engine division, General Motors Truck Co., *Detroit*, (mail) 12,749 Kentucky Avenue.

ALLEN, JAMES G. (A) engineer, Beneke-Kropf Mfg. Co., Chicago, (mail) 4691 Pacific Street, *Detroit*.

ANDERSON, ROY F. (M) chief engineer, Hayes-Ionia Co., *Grand Rapids, Mich.*, (mail) 1428 Logan Street, S. E.

ANTI-STALL, INC. (Aff) 100 East 42nd Street, *New York City*.
Representatives: Dunn, Arthur, Jr., secretary.
Gardiner, Carlos, manager of foreign department.
Maby, F. W., service manager.
Tucker, W. L., advertising manager.

BAKER, M. P. (J) technical secretary of experimental department, Oakland Motor Co., *Pontiac, Mich.*, (mail) 62 Joslyn Avenue.

BRACKETT, FRANK J. (M) field engineer, General Motors Corporation, 224 West 57th Street, *New York City*.

BURKE, JOSEPH EDWARD (A) purchasing agent, Dodge Bros. of Canada, Ltd., *Toronto, Ont., Canada*, (mail) 195 Quebec Avenue.

CHAMBERLIN, G. W. (A) sales engineer, Fruehauf Trailer Co., 10,940 Harper Avenue, *Detroit*.

CLARK, WILLIAM M. (A) superintendent of motor equipment, S. S. Pierce Co., *Boston*, (mail) 25 Jersey Street.

DECKARD, HOWARD C. (A) general superintendent, Taft-Peirce Mfg. Co., *Woonsocket, R. I.*, (mail) 45 Highland Street.

DICKINSON, J. H. (A) service manager, American Bosch Magneto Corporation, 3737 South Michigan Avenue, *Chicago*.

DORN, R. V. (A) draftsman, Kimball Motor Truck Corporation, Los Angeles, (mail) 924 North Marguerita Avenue, *Alhambra, Cal.*

FERGUSON, HAROLD G. (A) engineer, Automotive Valves Co., *Los Angeles*, (mail) 1614 Sargent Court.

FRANC, JOSEPH J. (A) assistant service manager, Oldsmobile Pittsburgh Co., Pittsburgh, (mail) 326 Reamer Avenue, *Carnegie, Pa.*

GENERAUX, GARFIELD D. (A) superintendent of automotive repair shops, Gilmore Oil Co., *Los Angeles*, (mail) 2350 West 31st Avenue.

GOUNDRY, ERVIN J. (A) salesman, Russell Mfg. Co., Middletown, Conn., (mail) 1932 East 97th Street, Suite 119, *Cleveland*.

HEINRICHS, ROBERT M. (J) sales engineer, Bendix Brake Co., Chicago, (mail) 225 Covington Drive, *Detroit*.

KENNEDY, MAJOR FRANK M. (S M) Air Service, McCook Field, *Dayton, Ohio*.

KNOPF, C. L. (M) lubrication engineer, doing manufacturers' development work and research, Sinclair Refining Co., New York City, (mail) 823 Montrose Avenue, *Chicago*.

KREBS, R. M. (A) compiling parts books, service department, Graham Bros., *Detroit*, (mail) 81 Montana Avenue, West.

LAMBERSON, A. R. (A) superintendent and automotive engineer, Westcott Burlingame, Inc., *Albany, N. Y.*, (mail) 241 New Scotland Avenue.

LEE, CHARLES L. (A) head of semi-works engineering division, General Motors Research Corporation, *Detroit*, (mail) 2707 Webb Avenue.

LIENHARD, GABRIEL (F M) chief engineer, Rhemag Riebe Werke, Riebe Strasse, *Berlin, Weissensee, Germany*.

LODGE, ALBERT (A) treasurer and general superintendent, E. A. Patch Co., Inc., 17 Ipswich Street, *Boston*.

LOWEKE, ERWIN F. (A) layout draftsman, Timken-Detroit Axle Co., *Detroit*, (mail) 12,731 Ardmore Avenue.

McTAVISH, RUSSELL C. (A) service representative, Durant Motors of Canada, Ltd., Leaside, *Toronto, Ont., Canada*.

MILLER, HERBERT L. (A) branch manager, Moreland Sales Corporation, Los Angeles, (mail) 35 Van Ness Avenue, *San Francisco*.

NEY, ALFRED M. (J) designer and builder of racing cars, European Motor Service, *New York City*, (mail) 30 West 87th Street.

PATTEN, H. H. (A) carbureter superintendent, Dave P. Kingsley Co., *Los Angeles*, (mail) 328 West 58th Street.

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